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ABSTRACT

The purpose of this study was to determine the relative effectiveness of two instructional approaches upon the attitude, achievement, and retention of fourth, fifth, and sixth graders studying a 3-week unit on the metric system. A laboratory approach, in which students measured three-dimensional objects with tools scaled in metric units, was compared to a simulation approach, in which students identified measurements of two-dimensional objects from pictures containing metric tools superimposed near the picture of the object to be measured. In both of these approaches, students first saw a slide/tape presentation prepared by the investigator. Then, self-instructional packages (following either the laboratory or the simulation approach) were given to students. A total of twelve intact classes from three elementary schools participated in the study. Schools were assigned at random to one of the two teaching approaches. Three investigator-constructed instruments were used: a student attitude questionnaire, a test of student knowledge, and a test of student ability to measure accurately using SI units (both laboratory and simulated items were on the test). The achievement test was used as an immediate posttest and again three weeks later as a retention test. When the data were analyzed, findings showed a significant difference in attitude of sixth graders, favoring the laboratory approach. On both the achievement posttest and retention test, no differences were found between scores of students in the laboratory group compared to those in the simulated activities group, at any grade level. Students in both groups scored significantly higher on the simulated items of the achievement and retention tests than on the laboratory items on the test. (DT)

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A COMPARISON OF INSTRUCTIONAL APPROACHES TO TEACHING THE INTERNATIONAL SYSTEM OF WEIGHTS AND MEASURES TO ELEMENTARY SCHOOL CHILDREN WITH VARYING MENTAL ABILITY

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FINAL REPORT

A COMPARISON OF INSTRUCTIONAL APPROACHES TO TEACHING THE INTERNATIONAL SYSTEM OF WEIGHTS AND MEASURES TO ELEMENTARY SCHOOL CHILDREN WITH VARYING MENTAL ABILITY

(Project No. 1194)

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August 31, 1976

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Chapter I

INTRODUCTION

The International System of Units (SI) is a simple and logical measuring plan. Its simplicity has prompted many nations to adopt it as their official measuring system. No nation that has adopted the International System of Units has ever abandoned it. Ninety percent of the world uses the International System of Units and 65 percent of all world production and trade is in SI.[1]

The number of nations adopting the International System of Units continues to grow with Great Britain being one of the last to make the change. Britain's action made it clear that the United States would soon be one of the very few nations using the customary system. As a result, the National Bureau of Standards decided in 1968 to conduct a study which was to evaluate the impact of the SI trend on the United States and to consider alternatives for national policy.[2]

> The United States Metric Study concludes that eventually the United States will join the rest of the world in the use of the metric system as the predominant common language of measurement. Rather than drifting to metric with no national plan to

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[1] Francis J. Parker, "Think Metric: It's Simple," American Vocational Journal, XLVIII (September, 1973), 35-37.

[2] Jeffrey V. Odom, "The Metric System; Learn It, Think It, Teach It," Instructor, LXXXIII (October, 1973), 59.

> help the sectors of our society and guide our relationships abroad, a carefully planned transition in which all sectors participate voluntarily is preferable.[3]

Developing such a national program for change would require a great deal of forethought and discussion. The study revealed that two major activities should be initiated which would serve as a foundation to prepare the rest of the nation for increased use of the International System of Units.

> The first is education. Every school child should have the opportunity to become as conversant with the metric system as he is with our present measurement system.[4]

> The second concerns international standards.[5]

It is fairly obvious that the educational system of the United States will be called upon to help make the transition from the customary system to the International System of Units. Educators will have the responsibility to begin designing instructional materials and strategies whereby the International System of Units might be taught most effectively.

There exists a great deal of literature on the instructional approaches to use when teaching the International System of Units. However, references that are made to the most effective instructional approaches in teaching the International System of Units are usually not supported by research.

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[3] U.S., Department of Commerce, National Bureau of Standards, U.S. Metric Study A Metric America: A Decision Whose Time Has Come (Washington, D.C.: Government Printing Office, 1971), p. xv.

[4] Ibid., p. xvi.

[5] Ibid.

The National Science Teachers Association Committee in a report to the National Bureau of Standards, stated:

> Little is known about the effectiveness of various methods of teaching the metric system to anyone--teachers or students. There is a great need for research to determine the best ways of teaching the metric system and ways of evaluating understanding and performance in the use of it.[6]

It is the opinion of many educators that the instructional approach used to teach the International System of Units should allow the learner to participate actively in measurement activities. However, there is insufficient evidence to indicate whether instructional approaches that require the learner to be actively involved in the manipulation of physical objects rather than an approach which does not involve the manipulation of physical objects are more conducive to learning the International System of Units.

Bright expressed his view when he stated that:

> A good way to develop familiarity is to really immerse them in the topic, with all sorts of related activities. The most obvious of these is the use of the metric units to measure objects in the school environment.[7]

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[6] National Science Teachers Association, "Metrication Urged by NSTA Committee," The Science Teacher, XXXVIII (January, 1971), 6.

[7] George W. Bright, "Metrics, Students, and You!" Instructor, LXXXIII (October, 1973), 64.

A similar opinion was expressed by the National Science Teachers Association Committee:

> In the absence of research findings, it is believed that the most effective method is to provide a concentrated period of time in which they have both extensive and intensive experience in the practical use of the metric system in a wide variety of physical measurements and in problem solving.[8]

Bugelski made a brief survey of research work done by leading psychologists on learning and action. It was found that studies pertaining to action in connection with learning followed several lines, both positive and negative, and ranged from research designed to test whether one could learn anything while asleep to comparisons between discussion and lecture sections of college courses. Bugelski reported that men such as Thorndike, Hull, Skinner, and Dewey based their entire thinking on the proposition that without action there is no learning, while Towman and Mowrer were among the theorists who claimed that learning can take place without action. Bugelski summarized the investigation with the following practical suggestions about active learning:

1. Activity is helpful for some kinds of learning and of little value to others.
2. Activity is not a universal condition for learning.
3. There seems to be no solid reason why teachers should always insist on action--on projects, on

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[8] National Science Teachers Association, op. cit., p. 6.

> participation, or on creating answers--in order for learning to occur. It all depends on what the student is learning.[9]

The reviewed literature would seem to indicate that (1) there is a need for research to determine the effectiveness of various instructional approaches in teaching the International System of Units, (2) that psychologists disagree regarding the importance of physical activities to learning, and (3) that the role of physical activities in learning will depend on the content being learned. On the other hand, many educators seem sure, without research evidence, that the International System of Units should be taught through activities.

Since educational systems will be called upon to help make the transition to the International System of Units, it follows that teachers should be equipped with the most effective instructional approaches in their presentations. As a result, there is an existing need for investigation of possible instructional approaches to teaching the International System of Units.

Statement of the Problem

A review of the literature indicates that psychologists and educators are in disagreement on the relative importance of activities in learning. It seems that they do agree on the point that the role of activities will be determined by the content being learned. However, the writer was unable to find research evidence that verified the role of activities when teaching the International System of Units, therefore, revealing the situational problem to which this study is directed.

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[9] B. R. Bugelski, The Psychology of Learning Applied to Teaching (New York: The Bobbs-Merrill Company, 1964), pp. 149-156.

Purpose of the Study

The purpose of this study was to ascertain the relative effect of two instructional approaches upon the attitude, achievement and retention of fourth, fifth and sixth grade students who studied the International System of Units. The instructional approaches are: (1) Approach A (laboratory activity) provides instruction by having students physically measure objects (three-dimensional in nature) with tools and instruments that are scaled in metric measures, and (2) Approach B (simulation activity) provides instruction by having students identify the measurements of objects (two-dimensional in nature) from pictures containing metric tools and instruments which are superimposed near the object to be measured.

A secondary purpose of this study was to ascertain the relative effect of two instructional approaches upon the attitude of the fourth, fifth and sixth grade teachers who taught the International System of Units.

Specifically, this study attempted to answer the following questions:

1. To what extent do Approach A and Approach B affect the attitude of fourth, fifth and sixth grade students who are studying the International System of Units?
2. To what extent do fourth, fifth and sixth grade students who are exposed to Approach A and Approach B increase their knowledge of the International System of Units?
3. To what extent do fourth, fifth and sixth grade students who are exposed to Approach A and Approach B retain information regarding the International System of Units?
4. To what extent do laboratory and simulated test types affect the achievement of fourth, fifth and sixth grade students who are studying the International System of Units?
5. To what extent do laboratory and simulated test types affect the retention of fourth, fifth and sixth grade students who are studying the International System of Units?
6. To what extent do Approach A and Approach B affect the attitude of fourth, fifth and sixth grade teachers who are teaching the International System of Units?

Statement of Hypotheses

The general research hypothesis for this study was that a significant difference would exist in attitude, achievement and retention among fourth, fifth and sixth grade students who have been exposed to the International System of Units by Approach A (laboratory activity) and Approach B (simulation activity). A second research hypothesis for this study was that a significant difference would exist between students' performance on the laboratory section and the simulated section of the achievement test and the test of retention.

Prior to testing the above hypotheses by analysis of covariance through multiple regression, Kerlinger and Pedhazur[10] emphasize that one should test for homogeneity of regression coefficients between each treatment group, since homogeneity of regression coefficients is assumed to be true in any application of the analysis of covariance. It was therefore necessary to test the hypothesis of whether there are differences in mental ability of students receiving instruction by Approach A and Approach B, for each section of the test by grade level.

The above general hypotheses were tested through the specific null hypotheses listed below.

> Ho_1: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the attitude scale on the mental ability scores, does not significantly improve the prediction of the scores of the attitude scale over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

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[10] Fred Kerlinger and Elazor Pedhazur, Multiple Regression in Behavioral Research (New York: Holt, Rinehart and Winston, Inc., 1973), p. 267.

Ho_2: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the cognitive achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_3: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_4: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_5: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_6: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_7: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_8: No significant difference exists between the scores students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_9: No significant interaction exists between the scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{10}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive retention test on mental ability scores, does not significantly improve the prediction of the scores of the cognitive retention test over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_{11}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_{12}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_{13}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{14}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the test of retention after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{15}: No significant difference exists between the scores students received on the laboratory section and the simulated section of the test of retention, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{16}: No significant interaction exists between the retention scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{17}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of all fourth, fifth and sixth grade students on the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units and mental ability are held constant.

Ho_{18}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of all fourth, fifth and sixth grade students on the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant.

Ho_{19}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of all fourth, fifth and sixth grade students on the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant.

Ho_{20}: No significant difference exists between teachers who taught the International System of Units by Approach A and those who taught by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units was held constant.

Definition of Terms

Achievement refers to the accomplishment or proficiency of performance in a given skill or body of knowledge as measured by an objective test over the informational content presented by the treatments.

Approach A refers to an instructional strategy whereby physical measurements of three-dimensional objects are taken in a laboratory setting by elementary students for the purpose of learning the basic units of the International System of Units.

Approach B refers to an instructional strategy whereby measurement activity is simulated pictorially in two-dimensional form for the purpose of assisting elementary school students in learning the basic units of the International System of Units.

Attitude refers to a tendency to react favorably or unfavorably toward a designed stimuli, i.e., to take a position or bearing as indicating feeling. As used in this study, attitude refers to the favorable or unfavorable feelings of students toward the International System of Units as assessed through the use of a researcher-prepared scale.

Cognitive, as used in this study, refers to non-laboratory or simulated measures of the students' knowledge or comprehension of the International System of Units, i.e., a paper and pencil assessment of a student's knowledge and comprehension of the International System of Units which involved no overt physical activity.

Content validity refers to the representativeness or sampling adequacy of the content--the substance, the matter, the topics--of the measuring instrument.[11]

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[11] L. Cronback and P. Meehl, "Construct Validity of Psychological Tests," Psychological Bulletin, LII (1955), 281-302.

Instrument refers to a test constructed by the investigator which was used as a posttest and as a retention test.

International System of Units (SI), popularly known as the modernized metric system, refers to the coherent system of units based upon and including the meter (length), kilogram (mass), second (time), kelvin (temperature), ampere (electric current), and candela (luminous intensity), as established by the General Conference on Weights and Measures in 1960, under the Treaty of the Meter. A seventh base unit, the mole (for the amount of substance) is being considered as another SI base unit. The radian (plane angle) and the steradian (solid angle) are supplemental units of the system.[12]

Laboratory measurement activities refer to the processes in which the student becomes involved in measuring the various three-dimensional objects with metric scales.

Laboratory section of the instrument refers to a type of testing instrument which attempted to determine the ability of the students to measure metrically through laboratory activities.

Metrication refers to any act tending to increase the use of the metric system (SI), whether it be increased use of metric units or of engineering standards that are based on such units.[13]

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[12] U.S. Department of Commerce, National Bureau of Standards, U.S. Metric Study the Consumer: Interim Report (Washington, D.C.: Government Printing Office, 1971), p. 139.

Metric system refers to the measurement system that commonly uses the meter for length, the kilogram for mass, the second for time, the degree Celsius (formerly referred to as "Centigrade") for temperature, and units derived from these. This system has evolved over the years and the modernized version today is identified as the "International System of Units," which is abbreviated, "SI."[14]

Reliability refers to the consistency between measurements in a series.[15]

Retention is the result of an experience occurring as a persisting after-effect that may serve as a basis for future modification of response of exercise. As used in this study, it refers to the amount of knowledge related to the International System of Units that the students retained over the six week time interval between the date the study was initiated and the date the test of retention was administered.

Scholastic aptitude is defined as the student's score measured by the Henmon-Nelson Tests of Mental Ability, Form 1.

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[13] Ibid., p. 139.

[14] Ibid.

[15] Steven Isaac and William Michael, *Handbook in Research and Evaluation* (San Diego: Robert R. Knapp, 1972), p. 87.

Simulated measurement activities refer to the processes whereby students are provided a picture of a two-dimensional object, along side of which a metric scale has been printed, and are then asked to read and record their findings.

Simulated section of the instrument refers to a type of testing instrument which attempted to determine the ability of the students to measure metrically through simulated activities.

Assumptions of the Study

This investigation was based on the following assumptions:

1. The researcher-prepared attitude scale, the test of initial achievement and the test of retention were valid and reliable.

2. The scores achieved by the subjects were a true measure of their ability to perform measuring tasks related to the International System of Units, regardless of the instructional approach to which they were assigned.

3. The test items of the posttest and test of retention represented the application level of the cognitive domain as described by Bloom.

4. The scores of the subjects in the treatment groups, as indicated by attitude scores along with achievement and retention test scores, were a function of the two instructional approaches.

5. Current course work and other concomitant experiences did not have an effect upon the students' abilities to perform measurement tasks related to the International System of Units.

6. Random assignment of schools to treatments had substantially the same effect upon the experiment as random assignment of individuals to treatments.

7. The random assignment of students to different sections of the fourth, fifth and sixth grade classes was not substantially different in effect from the random assignment of students to treatments.

8. Reading ability did not have an effect upon the students' achievement since both the instructional materials and instruments were read aloud by the participating teachers while the students completed the measurement activities.

9. It was assumed that the treatment groups were equivalent in manual dexterity since treatments were randomly assigned to schools.

Limitations of the Study

This investigation was organized and conducted within the following limits:

1. The study was limited to fourth, fifth and sixth grade students of the Warrensburg R-VI Public School District in Warrensburg, Missouri, during the spring quarter of 1975. Any generalization beyond the population

will be valid only to the extent that the sample of students experiencing the treatments was representative of other fourth, fifth and sixth grade students and to the extent that the teachers participating in the study were representative of fourth, fifth and sixth grade teachers in the participating school district.

2. The study was limited by the investigator's ability to construct valid and reliable achievement and retention test instruments which were used in the investigation.

3. The study was further limited to the two instructional approaches which utilized researcher-prepared film/slide and audio/tape presentations.

4. The selection of teachers for the study was limited to those teachers who had less than seven years of teaching experience as well as those who had received no formalized instruction on SI measurement.

5. Further generalizations are limited to the use of the same instruments employed in the study.

Method of Study

Data for this study were gathered from fourth, fifth and sixth grade students enrolled in Reese, Ridgeview and Southeast Elementary Schools, Warrensburg, Missouri. The study, which was conducted over a three week period during the spring quarter of the 1974-75 school year, was terminated with the administration of a posttest of achievement. This was followed by a test of retention which was administered three weeks after the completion of the posttest.

The instructional materials for the two treatments were subjected to a pilot study during the winter quarter of the 1974-75 school year, the quarter preceding the study. The students involved in the pilot study were enrolled in the upper elementary school grades of Central Elementary School, Warrensburg, Missouri. This study was used to evaluate the instructional procedures, the instructional packages and to validate the attitude scale and the achievement and retention test instruments.

Treatment variables. This study had as its experimental variable the type of related assignments that were used in the instructional approaches to teach the International System of Units. The two approaches were:

Approach A - This approach utilized assignments that required students to learn the basic units of the International System of Units through laboratory activities. The teachers in Approach A presented the necessary related information during the first part of the class period, utilizing a researcher-prepared slide/tape presentation. For the remainder of the class period, students were given a self-instructional package which required them to measure three-dimensional objects with metric tools and instruments. The teacher administered the self-instructional packages as well as supervised and maintained order in the classroom while students made their measurement.

Approach B - This approach required that students learn the basic units of the International System of Units through simulated activities. The teachers in Approach B utilized the same researcher-prepared slide/tape presentation as that utilized by teachers of Approach A. However, for the remainder of the period the students were administered a self-instructional package containing two-dimensional pictures, along side of which were printed the metric scales and instruments. The teacher supervised and maintained order in the classroom while students read the measurements on the printed representation of metric scales and instruments.

Assigning treatments to schools. Each of the two treatments (Approaches A and B) was assigned at random to (1) Ridgeview or (2) Southeast and Reese Elementary Schools. Reese and Southeast schools were randomly assigned to one approach since Reese Elementary School contained only the first four grades, whereas Southeast Elementary School housed grades five and six. A total of twelve intact classes, two at each of the three grade levels from each school, participated in this study.

Teacher selection. This study utilized twelve teachers who had signed a contract to teach the fourth, fifth and sixth grade at Reese, Ridgeview and Southeast Elementary Schools during the 1974-75 school year. Teachers involved in this study were selected on the following basis: (1) willingness to cooperate in the study, (2) comparability of years of teaching experience, (3) lack of formal instruction in SI measurement, (4) schedule compatibility, and (5) school to which they had been assigned.

Initial status of groups. As noted in a previous paragraph, intact classes were used in the experiment. To ascertain the degree to which the initial status of the groups varied, information was collected on the subjects' attitudes toward the International System of Units, their scholastic aptitudes and their prior knowledge of the International System of Units.

The scholastic aptitude scores of the subjects were taken from their permanent school records.

Prior knowledge of the International System of Units and the attitude of the students toward the International System of Units were ascertained by administering researcher-prepared achievement and attitude tests.

Preparation of attitude test. The attitude test used to assess the feeling of the students toward each instructional approach was developed by the researcher. Test items were administered to students participating in the pilot study in an effort to validate the instrument.

Preparation of achievement and retention tests. The tests of achievement and retention used to measure the effectiveness of each instructional approach were also developed by the researcher. Test items, constructed to measure the subjects' abilities to think at the application level of the cognitive domain, were administered to students participating in the pilot study in an effort to validate the instruments.

Analysis of data. Multiple regression analysis was the principal statistic used to test the null hypotheses. Kerlinger[16] recommends that the multiple regression procedure be used when the n's are unequal or whenever it is desirable to include one or two covariates for control purposes, both of which happen to be true in this study. To ascertain whether or not there was a significant difference between the achievement levels of students exposed to the two treatments, only the posttest and retention test scores were used.

Related Literature

The amount of literature written about the International System of Units has increased significantly in the last decade. Much of the literature pertaining to the International System of Units is devoted to explanations of SI measurement, arguments for and against its adoption, estimates of conversion costs and other related topics. In addition, there is an increased amount being written concerning the anticipated impact the International System of Units will have on education. The investigator reviewed recent research and literature as it pertained to: (1) the International System of Units in the curriculum; (2) recommendations for teaching the International System of Units; and (3) studies related to activity and learning.

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[16] F. N. Kerlinger, Foundations of Behavioral Research (New York: Holt, Rinehart and Winston, Inc., 1973), p. 646.

The International System of Units in the curriculum. The United States has long been aware of the advantages of having a standard method of measurement. Our customary system of measurement has met the needs of society down through the years. However, it seems that other nations have been equally successful with the SI system of measurement. In fact, since its introduction in France in 1790, it has swept most of the civilized world, and is now common language of commerce, industry, science and everyday living among 90 percent of the world's people.[17] It is apparent that if the United States continues to embrace what many consider an outmoded system of weights and measures, it is likely to suffer heavy financial losses in the world market place.

In 1968, the National Bureau of Standards conducted a study to determine the impact of increased worldwide use of the International System of Units on the United States. The NBS report, written in 1971, was transmitted to Congress with the recommendation of the Secretary of Commerce that the United States officially adopt the International System of Units, deliberately and carefully, over a ten-year period. It was further recommended that early priority be given to educating every American school child and the public.[18]

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[17] H. Manchester, "Here Comes the Meter," Reader's Digest, XLIII (April, 1972), 14.

In a 1972 article, Edson reported that should Congress decide to give metrication the green light, the educational establishment will have to play a vital part in introducing the International System of Units to the new generation that will use it. The author foresees a gradual changeover into SI of books, maps, instruments, courses and teaching methods, with the sciences leading the way and other subjects following along.[19] Neville expressed a similar opinion when he recommended that the educational system will be called upon to help make this transition from the customary system to SI.[20]

Bowles stated that as a result of the general use of the International System of Units in other countries and its use in science, elementary school children should acquire more familiarity with the system than is provided in current textbooks.[21] Jones emphasizes that SI should be taught as a system that will be used in the future rather than the current method of teaching it as a system that might be utilized.[22] Souers and Winslow maintain that measurement is inherent in the process of science and a knowledge of the International System of Units soon may be necessary, not only for every science student, but for every American as well.[23]

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[18] Odom, op. cit., p. 60.

[19] Lee Edson, "New Dimensions for Practically Everything--Metrication," American Education, XXI (April, 1972), 14.

[20] Harvey A. Neville, "Educating the Public in the Use of the Metric System," Journal of Chemical Education, II (July, 1925), 594.

In a 1973 article, Hallenberg reported that educators favored the International System of Units for the following reasons:[24]

1. The coordination of measures of length, area, volume and mass, combined with decimalization, facilitates computations.
2. The International System of Units is a simple and logically planned system. Its decimal basis conforms to our numeration system.
3. Once the system of prefixes has been learned, the uniformity in names for all types of

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[21] Richard D. Bowles, "The Metric System in Grade Six," The Arithmetic Teacher, XI (January, 1964), 38.

[22] Phillip G. Jones, "Metrics: Your Schools Will Be Teaching It," American School Board Journal, CLX (July, 1973), 23.

[23] C. V. Souers and D. R. Winslow, "Ideas to Stimulate Lessons in Measurement for Upper Elementary and Junior High School Students," School Science and Mathematics, LXVI (June, 1966), 532.

[24] Arthur E. Hallenberg, "The Metric System, Past, Present--Future," The Arithmetic Teacher, XX (April, 1973), 255.

measures makes for greater simplicity and ease in changing to more convenient-sized units for specific purposes.

4. The International System of Units requires less competence in the manipulation of common fractions, thus providing more time for other learning tasks.

Hough, chairman of the American Geophysical Study of the Metric System, reported that education would greatly benefit by changing from the English units to the International System of Units. It was estimated that 25 percent of a child and teacher's time could be saved in arithmetic courses if this change were made. It was concluded that SI adoption would greatly reduce the load in our grade schools and high schools in the curriculums that include both mathematics and the sciences.[25]

Fineblum stated that exceptional children learn the International System of Units more readily than they do the present system. The following reasons were cited:[26]

1. It allows teachers to teach in ascending order from concrete to the abstract more easily.

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[25] F. W. Hough, "Why Adopt the Metric System," Civil Engineering, XXX (November, 1960), 74.

[26] Carol Fineblum, "Key Issues Concerning the Adoption of the Metric System and Implications for the Education of Exceptional Children" (paper prepared for the Council for Exceptional Children, Arlington, Virginia, 1970), p. 6.

2. It can be used to teach the decimal concept showing its relationship to our own monetary system.
3. It is easier to read and remember.

In 1972, Manchester reported that a recent Gallup Poll indicated that the more people know about the International System of Units the more they favor its adoption; college graduates and professional people were among its leading advocates. It was also found that young people are more receptive than their elders to the International System of Units. Manchester indicates that the SI educational program should be done in large part through the elementary school children who can carry the language measurement experiences and computational exercises into the homes of our country.[27]

Bowles found that elementary students and teachers cannot be blamed for lack of information about the International System of Units. Upon inspecting eight series of arithmetic textbooks published between 1956 and 1963, it was discovered that only three mentioned the International System of Units in the sixth grade. It was also found that, from June 1953, to May 1963, Educational Index listed only eleven entries on the International System of Units of which seven were in journals not readily available to elementary school teachers.[28]

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[27] Manchester, op. cit., p. 23.

[28] Bowles, op. cit., p. 36.

Branscomb, in a 1971 article, reported that 10 percent of the elementary and intermediate students are exposed to a new science curriculum that includes the International System of Units. It was pointed out that the trend toward increased exposure to the International System of Units is detectable, but small, and it appears mainly in the new science curriculum. Branscomb also stated that in elementary and intermediate mathematics, a very small proportion of time is spent on measurement, and of that probably less than 20 percent is devoted to the International System of Units. It was pointed out that where the International System of Units is used, it is introduced as a second measurement language and no attempt is made to make the understanding and the use of the system instinctive.[29]

Jones reported on a UNESCO study that compared arithmetic achievement of school children in thirteen European countries. It was found that the children in England and Scotland, who were taught the "English" system, were found to be less proficient than those from countries on the European continent, who had been taught the International System of Units. The most probable explanation, the author concluded, was the difference in measurement systems that were used in instruction.[30]

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[29] Lewis M. Branscomb, "The U.S. Metric Study," The Science Teacher, XXXVIII (November, 1971), 58.

[30] Jones, op. cit., p. 24.

Roth, in a thesis prepared on the International System of Units, recommended that SI be taught in the private and public schools of the United States in the elementary grades and in doing this the English system should be de-emphasized. It was pointed out that textbooks should be prepared and revised as normally scheduled to highlight SI units. Roth recommended that SI units be followed by their English equivalents in brackets and then later issues could eliminate them.[31]

What significance does this have for teachers? In pointing to the needs of elementary students studying the International System of Units, Holmes and Snoble stated that elementary teachers should allow them to become familiar with the standard, gain an understanding of the superiority of a decimal subdivision, and then urge the students to use the International System of Units in all of their measurement activities. It was further suggested that the monetary system of the United States would be a good starting point for teaching the International System of Units.[32] Devilbiss discussed the combination of the

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[31] Norman H. Roth, "The Desirability and Practicability of Adoption of the Metric System in the United States," U.S. Congress, Senate, Committee on Commerce, Conversions to the Metric System, Hearings before Committee, Eighty-eighth Congress, 2nd Session, on S1278, January 7, 1964 (Washington, D.C.: Government Printing Office, 1964), pp. 25-48.

[32] N. J. Holmes and J. Snoble, "How to Teach Measurements in the Elementary Schools," NEA Publications Sale No. 471-14580 (Washington, D.C.: National Science Teachers Association, 1969), p. 10.

SI and the English systems used in industrial education classes. It was suggested that industrial arts teachers should make students aware of the type of measurements that they will be exposed to in their professions and occupations.[33] Hyek pointed out that business teachers will have the job of teaching a generation to use the system, accept the system, and to think with SI standards. It was reported that in some cases the SI change has begun with the introduction of the "new math" programs.[34]

Recommendations for teaching the International System of Units. Today, educators are continuously revising the school's curriculum in order to provide students with an education that will prepare them for the future world. Such a change is occurring in the area of measurement with the customary system being replaced by the International System of Units.

In a study concerning the knowledge students have of the International System of Units, Hinebaugh concluded that since SI units are so important in high school science and since such a large portion of children now go to high school, there seems excellent justification for including such units in the elementary curriculum.[35]

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[33] Joseph M. Devilbiss, "Can We Measure Up?" School Shop, XXVII (October, 1967), 51.

[34] J. L. Hyek, "The Metric System and the Business Teacher," Business Education World, XLVI (June, 1966), 16-17.

Streng emphasizes that familiarity with the terms and actual use of both the International System of Units and the English system of measurement is just as logical as foreign language at an early age. To make the system a useful tool rather than a barrier, the best approach is to start the enlightenment of elementary children, their teachers and the publishers of their books.[36]

Crane, in an article concerning when to teach the International System of Units, reported that she found that the third grade is a good time to introduce the systems of measurement. It was further pointed out that children are old enough to grasp the concepts and most of the terms used, and that they are young enough to have the bulk of science and mathematics still ahead of them.[37]

In a 1973 article, King and Whitman described the procedures being followed to convert the schools of Hawaii to the International System of Units. The authors found through administering a series of Piagetian-type tests to elementary students that they do not possess the concepts the concepts needed for measuring until sometime during the third grade. Consequently, it was recommended that formal instruction in measurement begin during the third grade and by the time students reach the sixth grade they should have an operational understanding of measurement.[38]

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[35] Oscar Hinebaugh, "Conclusion of the Vocabulary Study of English and Metric Units of Measurement," Educational Research Bulletin, VIII (April, 1929), 175-180.

[36] Evelyn Streng, "Meaningful Metric," School Science and Mathematics, LIV (May, 1964), 421-422.

[37] Beverly Crane, "The Metrics Are Coming," Grade Teacher, LXXXVIII (February, 1971), 88-89.

Helgrem advocated that the International System of Units be part of the education of all elementary students (Grades 1-8) throughout the school year with heavier emphasis placed at the upper six grades.[39] Zafforoni recommends that the International System of Units be taught at the intermediate grade level since it is part of the science courses at the secondary level.[40]

Wakeham,[41] as well as Viets,[42] stated that initial instruction in the International System of Units should emphasize the fundamental units--meter, gram, and liter--and the prefixes that indicate the multiples and submultiples of ten. Wakeham pointed out that it is unnecessary to teach the whole International System of Units and that three units each of length, volume, and weight suffice for all common purposes: meter, centimeter, millimeter; liter, milliliter, cubic centimeter; kilogram, gram, milligram.

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[38] Irv King and Nancy Whitman, "Going Metric in Hawaii," The Arithmetic Teacher, XX (April, 1973), 259.

[39] Fred Helgrem, "The Metric System in the Elementary Grades," The Arithmetic Teacher, XIV (May, 1967), 351.

[40] Joe Zafforoni, "Developing Concepts of Measurement," Instructor, LXXI (April, 1962), 33.

[41] G. Wakeham, "Note on Teaching the Metric System," Journal of Chemical Education, XXV (May, 1970), 134.

[42] Lottie Viets, "Experiences for Metric Missionaries," The Arithmetic Teacher, XX (April, 1973), 270.

Helgrem, in a 1967 article, indicated the ways by which the International System of Units might be taught by making the following suggestions:[43]

1. In the third grade, students should practice measuring to the nearest centimeter and should also learn to estimate metric lengths. This should be followed with simple problems in square and cubic measures in centimeter and meter.
2. In the fourth grade, there should be exercises in measuring to the nearest millimeter, estimating metric linear distances, and weighing to the nearest gram.
3. In the fifth grade, students should continue practice in measuring and estimating metric lengths followed by problems in volume or capacity and mass. Study should also be carried on to develop skill in conversion of one metric unit to a larger or smaller unit by a change in the position of the decimal point.

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[43] Helgrem, op. cit., p. 351.

4. In the sixth grade, time should be spent in review of the metric units learned in previous grades.

Bargman in a study to determine the most appropriate grade level for teaching the various phases of the International System of Units formulated the following guidelines:[44]

1. At grade three the following may be taught: (a) understanding the meaning and approximate sizes of various metric units of length, liquid volume, and weight; (b) ability to measure length, liquid volume, and weight using whole numbers; (c) understanding the organization of the metric system by multiples of tens; and (d) ability to perform simple conversions between metric units using whole numbers.
2. At grade four, the phases of the SI given in number one above and also the determination of area and cubic volume may be taught.
3. At grade five the phases of the SI given in numbers one and two above and also the following may be taught: (a) ability to measure length, liquid volume, and weight using decimals; and

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[44] John Bargman, "An Investigation of Elementary School Grade Levels Appropriate for Teaching the Metric System" (unpublished doctoral dissertation, Northwestern University, 1973).

(b) ability to perform conversions between metric units using decimals.

4. At grade six, the phases of the SI given in number one, number two, and number three above may be taught.

Recently, educators have expressed concern over whether conversion between the English and the International System of Units should be taught to elementary students. Westmeyer and McAda advised that no student's academic life should depend on his ability to make conversions between measuring systems and warned that conversion exercises could turn students against the International System of Units. The authors maintain that if SI is to be taught, students should be convinced of its importance and then get them to memorize the few names involved.[45]

Pray strongly emphasizes that conversion between the International System of Units and the English system should be eliminated entirely. It was emphasized that the object is not to enable the student to be able to convert, but to allow him to compare the two systems as separate entities--without confusing the issue by switching back and forth between them--and to let him decide which is the easier to handle.[46]

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[45] Paul Westmeyer and Harlene McAda, "Awkwards and Other Units," The Science Teacher, XXXIII (March, 1966), 62.

[46] Richard H. Pray, "The Metric System is Simple," The Arithmetic Teacher, VIII (April, 1961), 179.

In 1974, Brooks conducted a study to ascertain the effectiveness of two instructional approaches when teaching the International System of Units to seventh grade industrial arts students. The two instructional approaches were: (1) exclusively SI, and (2) SI in relationship to the customary system. Upon analyzing the achievement scores, Brooks concluded that teaching the International System of Units exclusively on its own is no more effective than teaching it in relationship to the customary system. However, in terms of retention scores, he concluded that instruction presented exclusively SI was significantly more effective for students with high mental ability than if SI is presented in relationship to the customary system.[47]

Educators are also interested in the most effective methods and techniques that can be used to teach the International System of Units. Lately, articles have emphasized that students learning the International System of Units be taught by methods that are activity oriented.

In a 1972 paper, Odom offered the following ideas on how to teach the International System of Units:

1. Teachers should emphasize learning by doing.
2. It is best if students learn to use metric units by measuring in metric units only.[48]

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[47] Howard J. Brooks, "A Comparison of Instructional Approaches in Teaching the Metric System to Seventh Grade Students With Varying Mental Ability" (unpublished doctoral dissertation, University of Missouri, Columbia, 1974).

[48] Odom, op. cit., p. 60.

Warning reported that researchers in sociology at Iowa State University have found that people advance through five stages before they can use a new system like the International System of Units. The stages are (1) awareness, (2) information gathering, (3) application, (4) trial, and (5) adoption. The third stage, which is the application stage, is where the learner begins to apply his knowledge by practicing measurement in SI units.[49]

Zafforoni,[50] Swan,[51] and Paige-Jennings[52] contend that the best way to gain some understanding of the International System of Units is to provide real life experiences with it. The authors maintain that emphasis should be placed on practical applications, and more problems could be devised which physically require the students to do some measuring. Swan recommended that students should be provided a multitude of experiences in the field--measuring distance, heights, areas, volumes, etc. Souers and Winslow also advocated that science teachers use activities that remove children from passive roles into more active roles, which produces in the learner the thrill of discovery and demands creative thinking.[53]

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[49] Margaret Warning, "Start Now to Think Metric," Journal of Home Economics, LXIV (December, 1972), 18-19.

[50] Zafforoni, op. cit., p. 33.

[51] Malcolm D. Swan, "Experience, Key to Metric Unit Conversion," The Science Teacher, XXXVII (November, 1970), 69.

[52] Donald Paige and Margaret Jennings, "Measurement in the Elementary School," The Arithmetic Teacher, XIV (May, 1967), 357.

Studies related to activity and learning. A review of educational literature revealed a variety of studies related to the effect of activities on learning. There were studies related to activities in the subject areas of industrial arts, science and mathematics. Although no research was discovered which varied the amount of activity when teaching the International System of Units, a review of related literature provides implications for this type of investigation.

In 1967, Pershern studied the effect of industrial arts activities on science achievement in the fourth, fifth and sixth grades. The experimental method consisted of integrating related industrial arts activities with science units, while the traditional method was characterized by lectures, discussion, reading-recitation, and other non-laboratory methods. Units of electricity and machines were used in the study. Pershern reported that, as a result of the unit of instruction on electricity, fourth and fifth grade students of the experimental method made significant gains in achievement at the .05 level of significance.[54]

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[53] Souers and Winslow, op. cit., p. 532.

[54] Frank R. Pershern, "The Effect of Industrial Arts Activities on Science Achievement and Pupil Attitudes in the Upper Elementary Grades" (unpublished doctoral dissertation, Texas A & M University, 1967).

Johnson designed a study to ascertain whether or not varying concrete activities affected the achievement of students in grades four, five and six. The Maximum treatment used a semi-programmed text together with two sets of physical models and instruments for each child to use as directed by the text. The Moderate treatment used the same programmed text as the Maximum treatment, but students were deprived of the models. The Minimum treatment used the same tests as did the other two treatments except that all drawings and illustrations were removed and verbal descriptors substituted. It was found that a high degree of concreteness yielded higher means on immediate achievement scores as well as higher retention scores.[55]

Sherman conducted a research study to ascertain the effectiveness of two methods of utilizing laboratory-type activities in teaching a physical science course; the direct manipulative approach and the indirect non-manipulative approach. The non-manipulative classes viewed projected slides which represented sequences of the same activities as those performed by the manipulative group. The manipulative group operated equipment. Sherman found no significant differences in achievement as a result of teaching the physical science course by the manipulative method as compared to the non-manipulative method.[56]

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[55] Robert L. Johnson, Jr., "Effects of Varying Concrete Activities on Achievement of Objectives in Perimeter, Area, and Volume by Students of Grades Four, Five, and Six" (unpublished doctoral dissertation, University of Colorado, 1970).

Schmitz, in a study comparing the effectiveness of utilizing two types of student participation in laboratory activities when teaching dimensional analysis in high school physics, found different results than did Sherman. The two methods of student participation were identical to those used by Sherman. Schmitz found that the mean achievement scores of the manipulative group were higher than those of the non-manipulative group. It was concluded that the manipulative laboratory activities contributed significantly to the level of achievement attained by students utilizing the elements of dimensional analysis.[57]

In 1967, Wright conducted a study to ascertain the differential effects of selected activities when used to supplement taped lecture presentations. The taped lecture presentation was the same for all treatments, but the activities varied. The activities were immediate dismissal after viewing the lecture, reference to a list of study questions during the lecture followed by dismissal after the lecture, writing a summary of the lecture, discussing the lecture with a teaching assistant, listening to or participating in a reaction panel selected from the treatment group, and working in buzz groups following the lecture. Upon analyzing the achievement test scores, Wright concluded that supplemental activities generally have a positive effect on student performance--and the lecture method, as a teaching technique, can be improved significantly by additional learning activities.[58]

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[56] Jack E. Sherman, "The Relative Effectiveness of Two Methods of Utilizing Laboratory-Type Activities in Teaching Introductory Physical Science" (unpublished doctoral dissertation, The University of Wisconsin, 1968).

[57] Francis Leo Schmitz, "A Comparison of the Relative Effectiveness of Utilizing Two Types of Student Participation in Laboratory Activities in Teaching Dimensional Analysis in High School Physics" (unpublished doctoral dissertation, The University of Wisconsin, 1970).

An experimental comparison of three approaches to teaching a fifth grade unit of science was conducted by Downs in 1968. The students in the three approaches had: (1) a laboratory constructional experience directly related to the unit of science under study, (2) a laboratory constructional experience which was unrelated to science, or (3) no constructional laboratory experience at all. Upon analysis of achievement test scores, Downs concluded that unrelated laboratory constructional experiences are superior to no laboratory constructional experiences at all but directly related laboratory constructional experiences are far superior to unrelated laboratory constructional experiences.[59]

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[58] Charles William Wright, "The Effect of Supplemental Activities on the Learning of Students in Taped Lecture Classes" (unpublished doctoral dissertation, The University of Nebraska, 1967).

[59] William Alan Downs, "The Effect of Constructional Activities Upon Achievement in the Areas of Science and Mathematics at the Fifth Grade Level" (unpublished doctoral dissertation, University of Missouri, Columbia, 1968).

Johnson's (1970) study involved seventh grade boys in a year-long study in a seven through twelve grade urban high school. The researcher attempted to identify the effectiveness of using activity oriented lessons in a mathematics class. Students were taught by one of the following three methods: (A) Text--Exclusive use of the textbook as the only mode of instruction, (B) Activity--Exclusive use of instructional modes other than the textbook, and (C) Enriched--A textbook-based mode which was augmented by enrichment activities from treatment (B). On the basis of the achievement tests, Johnson concluded that low and middle ability students are apparently aided in the learning of some concepts in seventh grade mathematics by the use of activity oriented lessons. No significant difference, however, was detected in achievement between activity-enriched and textbook-based instruction.[60]

Summary. Educators agreed that the present teaching of weights and measures is not only inadequate but also ineffective. Authorities also concurred that the International System of Units is becoming increasingly more important and that schools must find a place for it in the curriculum. Many of the articles favored introducing the

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[60] Randall E. Johnson, "The Effect of Activity Oriented Lessons on the Achievement and Attitudes of Seventh Grade Students in Mathematics" (unpublished doctoral dissertation, University of Minnesota, 1970).

International System of Units into our educational programs at the primary grade level.

Despite agreement about the importance and necessity of teaching the International System of Units, opinions varied widely as to the concepts that should be taught, the grade level they should be introduced, and whether conversion to English units should be taught. The issue of which methods to use when teaching the International System of Units was discussed extensively.

It would appear that, on the basis of the literature and research studies reported, no definite concensus of opinion has been reached concerning the effectiveness of utilizing activities when teaching the International System of Units in the elementary school.

All of the articles seem to indicate the possible need for such an approach, but research evidence to substantiate the argument for including an activity approach when teaching the International System of Units in the elementary curriculum is lacking. Therefore, this study was designed to provide answers to some of the questions concerning the use of activities in instruction related to the International System of Units.

Chapter II

DESIGN AND ORGANIZATION OF THE EXPERIMENT

In Chapter I the problem, purpose, hypotheses, definition of terms, assumptions, limitations, and method of study were stated along with a review of related literature.

Chapter II describes the design of the experiment along with the variables controlled, the nature and selection of the population, and the preparation of instructional materials. The results of the pilot study are also described along with a description of the physical facilities used in the study.

Research Design

This investigation was conducted as a nonequivalent control group design which is a quasi-experimental design as identified by Campbell and Stanley.[1] This design allowed the researcher to make comparisons between naturally assembled intact groups since the treatments were assigned at random to the groups.

One treatment group (Approach A) utilized assignments that required students to learn the basic units of SI measurement through laboratory activities. The other treatment group (Approach B) was required to learn the basic units of SI measurement through simulated activities.

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[1] Donald T. Campbell and Julian C. Stanley, Experimental and Quasi-Experimental Designs for Research (Chicago: Rand McNally and Company, 1963), p. 47.

The non-equivalent control group design is illustrated by the following symbols:

Laboratory group	O_1	X_A	O_2	O_3
Simulated group	O_1	X_B	O_2	O_3

The symbol O_1 represents the initial observation which was a pretest measure of attitude and prior knowledge that helped to ascertain group equivalence. The two treatments are symbolized by X_A for the laboratory approach and X_B for the simulated approach. The symbol O_2 represents the laboratory and simulated sections of the posttest measure along with posttest measures of attitude and knowledge, while O_3 indicates the readministration of the posttests described in O_2 as tests of retention, with the exception of the attitude measure.

According to Campbell and Stanley, the internal validity of this design might be weakened if the extraneous variables of history, maturation, testing, instrumentation, and regression go uncontrolled. They further explained that if the extraneous variables are not controlled, the difference, if any, between pretest and posttest scores may be due to the interaction effects of the extraneous variables rather than the effects of the treatments. They also suggested that since both treatment groups would be affected by the extraneous variables, the controlling factor should therefore be the pretest.[2] The classes within treatment groups were pretested and any initial difference which existed between the treatment groups were statistically adjusted by analysis of covariance through multiple regression.

Control Variables

In experimental research it is desirable to control all independent variables except those involved in the treatments. If this is possible, it can then be concluded that a certain relationship exists between the treatments (Approach A and B) and the dependent variable (SI achievement test).

In this study the following variables were held constant, insofar as possible, for both groups participating in the study:

1. Self-contained classroom organization
2. Grade levels
3. Subject matter area
4. Unit plans on measurement
5. Objectives measured
6. Number of activities
7. Sequence of presentation
8. Format of lessons

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[2] Ibid., p. 48.

9. Date presentation of content was initiated
10. Maximum number of minutes spent on a lesson
11. Class time
12. Dates and times tests were administered
13. Classwork done outside of controlled conditions
14. Scales, pretests, posttests, and tests of retention
15. Date presentation of content was completed
16. Slide/tape presentations

Other variables which were beyond the control of the investigator which may have had an effect on the experiment were assumed to have had an equal effect on both groups.

The study utilized four fourth, four fifth and four sixth grade teachers from Reese, Ridgeview and Southeast Elementary Schools. The teachers administered the self-instructional packages and the evaluation instruments as well as supervised and maintained order in the classroom. The slide/tape presentations and the unit lessons were also of a self-instructional format. In an effort to control reading ability, teachers were required to read the scales, test instruments and unit lessons to the students, but were requested not to answer any questions that students might have concerning the International System of Units. This latter requirement was designed to control teacher influence.

Students were told that the Warrensburg R-VI Board of Education had decided to include SI as part of the fourth, fifth and sixth grade curriculum and that two instructors from Central Missouri State University would be assisting their teachers. Students were requested: (1) not to discuss the project with other fourth, fifth and sixth grade students, and (2) to perform to the best of their ability. They were also told that their teachers would not be able to answer questions concerning SI measurement during the project.

Nature and Selection of Population

Permission to conduct the study was obtained from the Warrensburg R-VI Board of Education during the second semester of the 1973-74 school year. The experiment itself was conducted during the second semester of the 1974-75 school year. A sample of four fourth, four fifth and four sixth grade classes was selected from a population of six fourth, six fifth and six sixth grade classes. Two of the six fourth grade classes were located at Reese, Ridgeview and Southeast Elementary Schools. Three of the fifth grade and three of the sixth grade classes were located in Ridgeview and Southeast Elementary Schools. A sample of two fourth grade classes, two from Reese and two from Southeast Elementary Schools were chosen along with two fifth and two sixth grade classes from both Ridgeview and Southeast Elementary Schools.

All but two of the sixteen upper elementary teachers located in these three schools had expressed a willingness to participate in the study. The two fourth grade teachers who expressed a desire not to participate in the study did so for personal reasons. A comparison of years of teaching experience revealed that twelve of the teachers, two from Reese, four at Southeast and six at Ridgeview, had less than seven years of teaching experience, while the other two sixth grade teachers at Ridgeview had more than thirteen years of teaching experience. Since comparability of years of teaching experience was one of the limitations of the study, those teachers who had less than seven years of teaching experience were selected for inclusion in the study.

The study, which consisted of 115 fourth grade, 104 fifth grade and 109 sixth grade students, was designed to accept intact groups of students who were assigned to their classes by normal scheduling procedures. The four fourth grade classes had an average enrollment of twenty-nine students each, while the four fifth grade classes had an average enrollment of twenty-six students each and the four sixth grade classes had an average enrollment of twenty-seven students each.

Some students enrolled in each of the twelve classes were not included in the analysis of the data due to one or more of the factors listed below:

1. Complete pretest, posttest, and retention test scores were not available.
2. Absenteeism during all or part of the treatment.
3. Mental ability scores were not available.

Data for the final analysis are based on the performance of 252 students in grades four, five and six. One hundred twenty-three students comprised the sample for Approach A and 129 students comprised the sample for Approach B. Composite scores of each student are reported by grade level by instructional approach. (Appendix A)

Table I shows the distribution of the total research population of 252 students by approach and grade level.

TABLE I

DISTRIBUTION OF THE RESEARCH POPULATION*
BY APPROACH AND GRADE LEVEL

Grade Levels	Approach A	Approach B	Total
Fourth	41	42	83
Fifth	41	41	82
Sixth	41	46	87

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*252 students in grades four, five and six

Instructional Materials and Procedures

The instructional materials were prepared by the researcher based on the review of the literature pertaining to basic measures of the International System of Units. The instructional materials were limited to the SI units of length, volume, mass and temperature that are taught at the fourth, fifth and/or sixth grade levels. Each unit was designed to be (1) self-instructional, (2) easily transportable, (3) self-contained, and (4) inexpensive.

The sequence of instructional activities, as shown in Figure 1, was followed for the purpose of controlling the instructional variables. The only differences in instruction that existed between the three grade levels were (1) the treatments (Approach B and B), since both groups received the same information at each grade level through the use of common slide/tape series, (2) the depth of study of the International System of Units as a given grade level, and (3) the total time spent on instruction at a given grade level. Student activities for instructional Approach A were based upon laboratory experiences, while the activities for instructional Approach B were based upon simulated experiences. Regardless of instructional approach, the activities were based upon the same concepts of SI measurement.

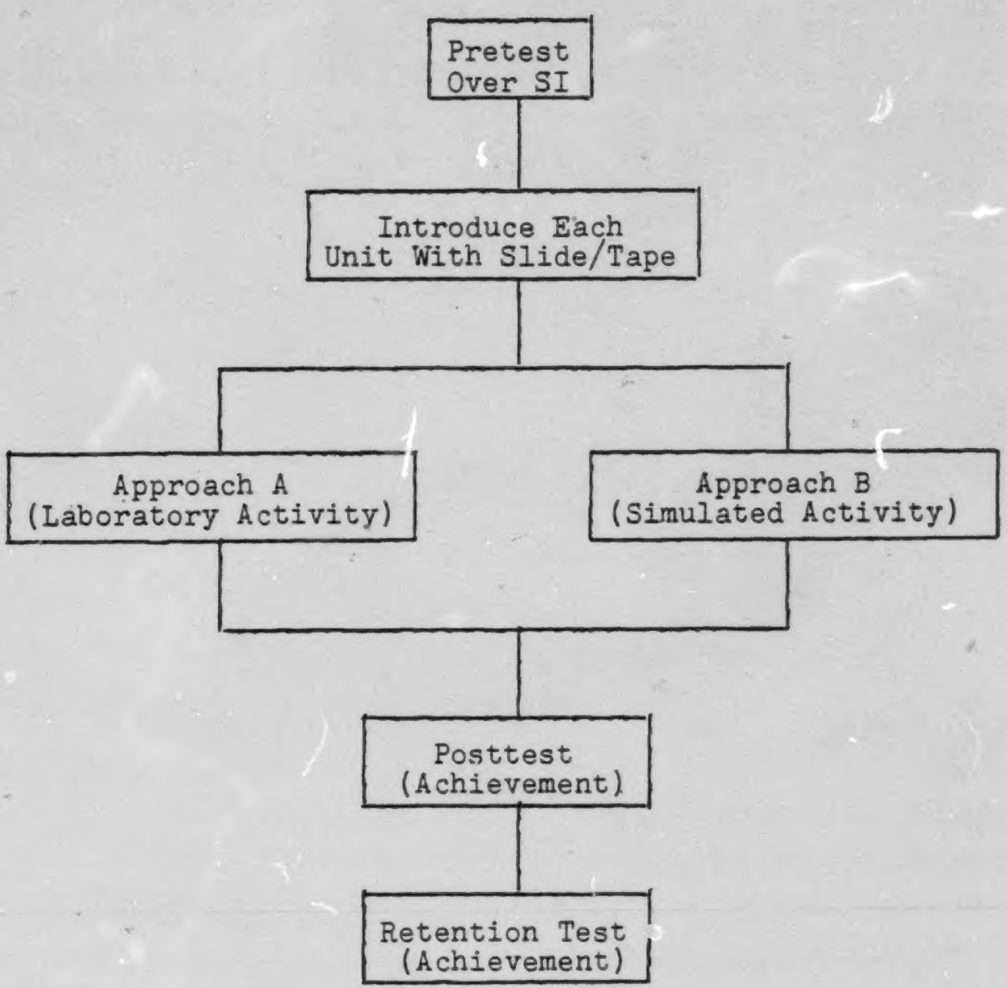
Pretest
Over SI
Introduce Each
Unit With Slide/Tape
Approach A
(Laboratory Activity)
Approach B
(Simulated Activity)
Posttest
(Achievement)
Retention Test
(Achievement)

FIGURE 1

SEQUENCE OF INSTRUCTIONAL ACTIVITIES

Preparing the Instructional Materials

Development of the objectives. The instructional objectives for this study focused upon the type of learning related to the cognitive domain as described by Bloom.[3]

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[3] Benjamin S. Bloom, et al, Taxonomy of Educational Objectives, Handbook I: Cognitive Domain (New York: David McKay Company, Inc., 1965), pp. 62-143.

More specifically, the objectives were those pertaining to:

1. Knowledge of terminology
2. Knowledge of specific facts
3. Comprehension - translation
4. Comprehension - interpretation
5. Application

The lessons, for which objectives were developed, included the following basic measuring units of the International System of Units: (1) linear, (2) volume (capacity), (3) weight (mass), and (4) temperature. Within each lesson, the researcher prepared specific objectives that corresponded to the following outline (Appendix B):

I. Identify SI unit
II. SI measuring tools
III. Relationships between SI units
IV. Examples of SI unit
V. Estimating in SI unit
VI. Measuring in SI units

Development of the slide/tape. The slide/tape series used in this study was developed by the researcher. The text for these tapes is included as a part of this report. (Appendix C) A slide/tape was prepared for each of the four measuring units utilized in the study. The content of each slide/tape was based on the instructional objectives prepared by the researcher for a given grade level. The slide/tapes developed for each grade level were somewhat different. The total fourth grade slide/tapes served as a preface to the longer slide/tapes used by the fifth grade. This was also the case for the slide/tapes used by the sixth grade. This allowed the researcher to include more complex concepts at the fifth and then even more complex concepts at the sixth grade level. Upon completion of the slide/tape series by grade level, each slide/tape was evaluated for content validity by a panel of judges. The developer then revised the slide/tapes, basing his revisions on recommendations made by the panel of judges.

Development of the unit lessons. To alleviate any possible treatment variations that could have occurred in the fourth, fifth and sixth grade classes, lessons of a self-instructional format were utilized with both treatment groups. The lessons for each treatment group (Approaches A and B) varied only by: (1) the way the activities were presented and solved and (2) the International System of Units studied at a given grade level. The lessons for Approach A (laboratory activity) required students to solve an activity by physically measuring a three-dimensional object with a metric scale and then recording their findings (Appendix D). In the lessons for Approach B (simulation activity), an identical activity was used with the exception that the measurements were read and recorded from a picture of the object, along side of which a metric scale had been printed (Appendix E).

The lessons were developed around the instructional objectives listed in Appendix B. Each lesson was designed to allow students to first estimate measurements and then to check their estimate by physically measuring (Approach A) or by reading a printed scale (Approach B). All lessons were initiated with the standard base unit of SI measurement and were followed by multiples and submultiples of that unit. The capacity of the measuring instruments tended to limit the size of the objects to be measured.

With the above ideas in mind, a number of activities were selected for each lesson. Selection was limited to activities that could be completed during the period of the experiment. Activities were further limited by the: (1) grade level of the students, (2) cost of the object, (3) availability of the object, and (4) size of the object.

Upon completion of the lessons, they were evaluated by a panel of judges who checked, by grade level, for the accuracy of content, similarities in lessons between approaches, clarity of instructions, and relevance to stated objectives. The researcher then revised the lessons basing his revisions on recommendations made by the panel of judges. The lessons were then subjected to a pilot study.

Development of the instruments. The instruments used to assess attitude, measure achievement and measure retention in this study were designed and prepared by the researcher. The achievement and retention measures were designed to test the student's ability to respond to the application level of the cognitive domain. The attitude scale and the achievement test were administered as a post-measure at the conclusion of the experimental period. The achievement test was also administered as a test of retention three weeks later. (Appendix F) There were three different instruments used in the study. One instrument was designed to assess student attitude, another to assess student knowledge and the third to assess a student's ability to measure accurately using SI measures. This latter instrument consisted of a separate section for both laboratory and simulated test items. Test items within each section were constructed so that they would differ in only two respects, i.e., (1) the size of the object being measured, and (2) the approach used to measure the object, which was the treatment variable.

All of the instruments used in the study were subjected to a panel of judges for the establishment of content validity. The researcher revised the instrument basing his revisions on recommendations made by the panel of judges and then subjected the instrument to a pilot study.

Twenty-two upper elementary school students enrolled in the Laboratory School of Central Missouri State University comprised the pilot study. The answer sheets were machine scored by the Testing Center of Central

Missouri State University and were analyzed by the Computer Center, also located on the campus. An item analysis, utilized to ascertain the effectiveness of the test items, supplied the researcher with measures of item difficulty, point-biserial correlation and a reliability coefficient. This latter measure was obtained through an application of the Kuder-Richardson Formula 20.[4]

Forty-six statements about measurement were developed by the researcher for the attitude scale with five responses per scale item. A reliability coefficient of .912, with a standard error of measurement of 2.443 was obtained for the attitude scale. Sixteen of the original forty-six items which exhibited a correlation of less than .10, were discarded. Nunnally[5] supports this approach by stating that it is more desirable to construct a test based on the point-biserial correlation of items rather than on item difficulty. Of the original forty-six statements, thirty were retained for the final attitude scale which was used to assess the student feelings toward the International System of Units.

Thirty-one multiple choice items were constructed for the cognitive instrument, i.e., the instrument which was used to assess student knowledge of the International

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[4] J. P. Guilford, Fundamental Statistics in Psychology and Education (New York: McGraw-Hill Book Company, 1965), pp. 458-462.

[5] Jum C. Nunnally, Psychometric Theory (New York: McGraw-Hill Book Company, 1967), p. 254.

System of Units. This instrument, like all of the instruments used in the study, had five responses per test item. A reliability coefficient of .764, with a standard error of measurement of 2.376 was obtained for this instrument. One of the original thirty-one items was discarded since it exhibited a correlation of less than .10, leaving thirty items for the final test instrument.

Sixty multiple choice items were constructed, thirty for the laboratory section and thirty for the simulated section of the instruments which were designed to assess the ability of the students to make SI measurements. Each test item was followed by five responses. A reliability coefficient of .711, with a standard error of measurement of 1.561 was obtained from the laboratory section of the instrument, while the simulated section had a reliability coefficient of .802 and a standard error of measurement of 1.477.

The researcher also utilized the point-biserial correlations to select the items for the final laboratory and simulated sections of the instrument, also discarding items exhibiting a correlation of less than .10. Of the original sixty test items, twenty-seven items from both the laboratory and simulated section of the achievement test were retained for use in the final instruments. (Appendix F).

At the completion of the pilot study, a second application of the Kuder-Richardson Formula 20 was applied to the data obtained from the application of the final laboratory and simulated sections of the instrument. This analysis revealed reliability coefficients of .718 on the laboratory section and .839 on the simulated section of the achievement test. The standard error of measurement for the laboratory section was 1.476, while the standard error of measurement for the simulated section was 1.331. Thorndike and Hagen[6] reported that a reliability coefficient of this magnitude was sufficient for the comparison of groups of students.

Pilot Study

The pilot study, conducted two weeks prior to the major experiment, was used to evaluate and regulate the instructional procedures, self-instructional lessons, and to validate the instruments.

A total of twenty-two fifth and sixth grade students were randomly assigned to Approach A or Approach B. The students were then administered the attitude scale which was followed by the cognitive instrument. All of the students, regardless of approach, were then presented the first slide/tape which covered materials related to Lesson I. Following the slide/tape presentation, the students of both approaches were directed to separate classrooms where the first lesson was administered. Each student received a copy of the lesson and was asked to silently read Lesson I while their instructor read the contents aloud.

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[6] Robert L. Thorndike and Elizabeth Hagen, Measurement and Evaluation in Psychology and Education (New York: John Wiley and Sons, Inc., 1961), p. 190.

The procedures outlined for Lesson I were also followed for Lessons II through IV. After completing Lesson IV, students were administered the researcher-prepared attitude, cognitive and laboratory and/or simulated achievement instruments.

It was evident from students' comments and the observations made by the researcher during the pilot study, that several changes were imperative. In an effort to keep the work stations cleaner, it was decided to substitute sand for water whenever possible and that the sand be poured and measured inside the lid of the kit at the work station. The large number of items in the kit (32 items), from which the students had to choose, caused a time delay. To alleviate this problem in the actual experiment, only those items needed for the unit lesson being studied were placed in the kit. Finally, a string located in the pilot study kit became easily tangled during the measuring process. This problem was corrected by replacing the string with a piece of ribbon.

There were no major problems with the slide/tape presentations that were utilized in the study. After the pilot study was completed, all necessary changes were made. and the slide/tapes, lessons and instruments were prepared for the actual experiment.

Physical Facilities

The actual experiment was conducted in four fourth, four fifth and four sixth grade classrooms, two fourth grade classes from Reese, two fifth grade and two sixth grade classes from Southeast along with two fourth, two fifth and two sixth grade classes from Ridgeview Elementary Schools. The instructional materials and procedures utilized in each of the four fourth, four fifth and four sixth grade rooms within each of the three schools were identical by grade level, although the physical layout of the rooms did vary. All rooms were well lighted and had adequate ventilation and heating. The rooms were arranged so that students could easily view the slide/tape presentation on the screen from their desk (Appendix G).

The rooms were well equipped with student desks, teacher desk, projection screen, slide projector and tape recorder. In addition to this equipment, a large table was placed at the back of the six rooms where Approach A was being utilized. Each table was divided into six work stations (cubicles constructed with cardboard) which prevented students from observing each other during the measuring activity.

The metric scales and objects to be measured were stored in a kit below each work station. Students were asked to do their measuring inside the lid of the kit which had been placed on the table at their work station (Appendix G).

In an effort to expedite administration of the laboratory and simulated sections of the posttest and the test of retention, three tables (eighteen work stations) were set up in the multi-purpose room of each school. Each group of students could be observed while they completed their test instruments since the tables radiated out from the instructor (Appendix H).

Summary

This study was conducted as a nonequivalent control group design which is a quasi-experimental design with random assignment of treatments to intact groups. The design was used to ascertain the effect of the two treatments, laboratory or simulated activities, on the dependent variable. Through this type of design every effort is made to control all extraneous variables and to maximize the effects of the treatments.

The instructional materials prepared for this study included slide/tapes, laboratory/simulated lessons, and instruments. The instructional materials and instruments were modified and improved on the basis of suggestions by a panel of judges.

Two weeks prior to the actual experiment a pilot study was conducted to evaluate and regulate the instructional procedures and self-instructional lessons, and to validate the instruments. The pilot study was conducted in the upper elementary school grades of the Laboratory

School of Central Missouri State University, Warrensburg, Missouri.

The sample selected from a population of six fourth, six fifth and six sixth grade classes consisted of two classes at Reese, four classes at Southeast and six classes at Ridgeview Elementary Schools, Warrensburg, Missouri. The study was conducted during the second semester of the 1974-75 school year.

Chapter III

CONDUCTING THE EXPERIMENT

The previous chapter describes the research design, control variables, nature and selection of the population, instructional materials and procedures, and the preparation of instructional materials. The results of the pilot study were also discussed along with the physical facilities utilized in the experiment. Chapter III describes the procedures followed in conducting the experiment.

Preparation for the Experiment

Final approval to conduct this research study at the fourth, fifth and sixth grade levels in Reese, Ridgeview and Southeast Elementary Schools was obtained from the Warrensburg R-VI Board of Education. After permission was granted, the researcher met in early September of 1974 with the principals and four fourth, four fifth and four sixth grade teachers of the three elementary schools to acquaint them with the nature of the experiment. Since the Warrensburg R-VI Board of Education had earlier advised the elementary, junior high and senior high school administrations to begin planning for conversion to the International System of Units, the principals and teachers were very receptive to a study of this nature.

Orientation Meeting

Prior to starting the experiment, the participating teachers and principals were asked to attend an orientation meeting. During this meeting, they were familiarized with the instructional activities that would be followed during the experiment (see page 52). The participants first viewed a portion [illegible] the researcher-prepared slide/tape series related [illegible] Lesson I. Following the slide/tape presentation, the teachers and their principals were shown an example of Lesson I and its accompanying answer sheet. The researcher then outlined all of the lessons as follows:

I. Lesson I - INTRODUCTION TO SI MEASUREMENT
II. Lesson II - PREFIXES AND SUFFIXES IN SI MEASUREMENT
III. Lesson III - LINEAR IN SI MEASUREMENT
IV. Lesson IV - CAPACITY/VOLUME IN SI MEASUREMENT
V. Lesson V - MASS/WEIGHT IN SI MEASUREMENT
VI. Lesson VI - TEMPERATURE IN SI MEASUREMENT

The researcher also outlined the SI units which would be included in each lesson, by grade level. This breakdown is shown in Figure 2.

	GRADE LEVELS		
LESSONS	(Fourth)	(Fifth)	(Sixth)
I	(lesson was the same for all grades)		
II	deci kilo	deci kilo centi milli	deci kilo centi milli
III	meter decimeter	meter decimeter centimeter	meter decimeter centimeter kilometer
IV	liter	liter milliliter	liter milliliter
V	kilogram	kilogram gram	kilogram gram
VI	Celsius	Celsius	Celsius

FIGURE 2

SI UNITS, PREFIXES AND SUFFIXES

BY GRADE LEVEL

In addition to the lessons outlined, a proposed research schedule was submitted to the participants for their approval. The teachers at each grade level recommended that: (1) minor changes be made in the research schedule for their particular grade to make the schedule more compatible with their existing class schedules, and

(2) the common time for the research activities be conducted between eleven and twelve o'clock each day. The schedule cited in Figure 3 was approved by both the teachers and their principals and was followed throughout the experiment.

DAYS	LABORATORY APPROACH (Reese & Southeast)	SIMULATED APPROACH (Ridgeview)
1	Attitude Pretest	Attitude Pretest
1	Cognitive Pretest	Cognitive Pretest
2	Lesson #I	Lesson #I
3	Lesson #II	Lesson #II
4-6	Lesson #III	Lesson #III
7-10	Lesson #IV	Lesson #IV
11-13	Lesson #V	Lesson #V
14	Lesson #VI	Lesson #VI
14	Attitude Posttest	Attitude Posttest
14	Cognitive Posttest	Cognitive Posttest
15	Laboratory Posttest	Simulated Posttest
16	Simulated Posttest	Laboratory Posttest
17	Cognitive Retention Test	Cognitive Retention Test
17	Laboratory Retention Test	Simulated Retention Test
18	Simulated Retention Test	Laboratory Retention Test

FIGURE 3

SCHEDULE OF CLASSES

Finally, the participants were divided into two groups by randomly assigning instructional Approach A to Reese and Southeast Elementary Schools and instructional Approach B to Ridgeview Elementary School. Each group was then provided with a detailed procedure for carrying out the study along with an example of the type of activity their students would experience. This was done in separate rooms by instructional approach.

Initial Status of the Groups

In this study it was not possible for the researcher to randomly assign students to treatments since the students had already been assigned to classes in advance of the researcher's initial contact with the schools. Therefore, the researcher accepted the classes as they were scheduled and randomly assigned treatments to the intact classes. Under these conditions the researcher utilized the analysis of covariance through multiple regression research procedure for purposes of analyzing data collected from the study. This technique takes into account, or adjusts for, initial differences that may exist between the treatment groups due to the following covariates: (1) attitude toward SI measurement, (2) knowledge of SI measurement, and (3) mental ability.

The students' attitudes toward SI measurement were assessed by administering an attitude scale which had been constructed by the researcher. This scale was the first instrument to be administered as a part of the study. Individual scores obtained from use of this scale are reported in Appendix A, by instructional approach.

The students' knowledge of the International System of Units was assessed by administering a cognitive pretest which was constructed by the researcher. The individual scores obtained from this pretest are reported in Appendix A, by instructional approach.

The students' mental ability was measured by administering the Henmon-Nelson Tests of Mental Ability, Form 1, to all three upper elementary grades in the three participating schools. Mrs. Mary Elliott, Elementary School Guidance Counselor, assisted the researcher in administering this instrument during the fall semester of 1974. Individual mental ability scores are reported in Appendix A, by instructional approach.

Instructional Procedures

The actual experiment was conducted over a three week period, beginning on Friday, April 4, 1975, and ending on Friday, April 25, 1975. The pretests were administered on April 4, while the posttests were administered on April 23, 24 and 25. The tests of retention were administered on May 15 and 16, 1975, three weeks after the administration of the posttests. The classes participating in each instructional approach were supervised by the regular classroom teacher who also administered all of the evaluation instruments.

General Procedures

Each teacher was given a list of procedures to follow while administering the self-instructional lessons in an attempt to hold the instructional variables constant. The instructional materials utilized during a unit lesson were delivered to the classroom on the day preceding the date when the lesson would be presented. They were then organized by the researcher for each lesson according to the instructional approach being used (Appendixes D and E).

The students, regardless of instructional approach, were introduced to each lesson by a common slide/tape. With the exception of Lesson I, Introduction to SI Measurement, and Lesson II, Prefixes and Suffixes in SI Measurement, all slide/tape presentations were followed by a related lesson which was the treatment variable. All students received a copy of the lesson along with an answer sheet and were asked to read the contents silently as their teacher read it aloud. The time allotted for each lesson was the same for both treatment groups within a given grade level. The time allotted to each grade level did vary since there were more units, prefixes and suffixes being studied at the fifth grade level than at the fourth grade level. The same concept held true for grade six over grade five. This is illustrated in Figure 2 (see page 66). Throughout the experiment, students were told to record the amount of time it actually took them to complete each lesson. This information was used as a check to assess the amount of time which should be allotted for a given instructional approach. At the end of each lesson, the students were asked to check their answers with the key provided by the teacher. Although the questions requiring the students to estimate a measurement were not scored, each student was nevertheless encouraged to note the differences between his estimated and measured response. It was felt that through this self-instructional approach, students would be able to better assess their understanding of SI measurement. The completed lessons and answer sheets were collected at the end of each class period by the teacher.

Daily Procedures

More specific information about the day-to-day procedures that were followed throughout the experiment are presented in this section. The procedures are discussed in terms of those pertaining to: (1) both experimental groups (Approaches A and B), (2) only group A (Approach A), and (3) only group B (Approach B). The schedule of classes is presented in Figure 3 (see page 67).

Day 1. Both experimental groups were administered the researcher-prepared attitude scale and the cognitive pretest on the International System of Units (Appendix I & J). The evaluation instruments and computer answer sheets were furnished to the students by the teacher while the students supplied their own soft lead pencils. The general directions preceding each evaluation instrument helped students to complete the information requested at the top of the answer sheet as well as to record their answers. The teachers read each test item aloud while the students read them silently. Sufficient time was then allowed for the students to record their response. After the testing session, the teachers collected all test booklets and answer sheets.

Day 2. Lesson I which was entitled, "Introduction to SI Measurement," was presented to both experimental groups by a common slide/tape. The slide/tape presentation included the history of measurement, SI units and their relationships, and the advantages of adopting SI measurement. Following the slide/tape presentation, students were informed that the program would continue the next day with Lesson II. The script for the slide/tape which was used in Lesson I is located in Appendix C.

Day 3. Students in both experimental groups were administered Lesson II through the common slide/tape entitled, "Prefixes and Suffixes in SI Measurement." This slide/tape included an explanation of the most frequently used prefixes and suffixes along with the symbols that were used to represent them. At the end of the slide/tape presentation, students were told that the program would continue the next day with Lesson III. The slide/tape script for Lesson II is located in Appendix C.

Days 4-6. During the first of the three days spent on this unit, both experimental groups received instruction through the common slide/tape for Lesson III entitled, "Linear in SI Measurement." This slide/tape included a study of the multiples and sub-multiples of the base unit, meter, their symbols, and the instruments used to measure each unit of length. The remaining two days were spent in administering the treatment variables to the two instructional approaches. The maximum amount of time allotted for the treatment variables was fifteen minutes for grade four, twenty-five minutes for grade five, and thirty minutes for grade six. This treatment was to be administered over the remaining two days of this lesson following the specified time allocations for a given grade level.

Group A students physically measured the length of three-dimensional objects with metric scales which were located at each of the six work stations (Appendix D). The general procedures were the same as those described earlier in Chapter III, with the exception of a few procedures which were unique to this group. Students in this group were required to complete the odd numbered sections of each lesson as a class, since the odd numbered sections served to reinforce the slide/tape series as well as to provide example problems. The even numbered sections of the lesson were completed by groups of six students. During administration of the even numbered sections of the lesson, students not participating were involved in regular classroom activities. The above procedure was repeated for each odd and even numbered section of the lesson. Students were encouraged to move quickly and quietly to and from the work stations.

Students in group B were provided two-dimensional pictures of objects along side of which a metric scale had been printed (Appendix E). The students were asked to identify the size of each object and to record their responses. The general procedures for group B were the same as those described earlier in Chapter III, with the exception of a few procedures which were unique to this group. Students in group B were also required to complete the odd numbered sections as a class since these sections were identical for groups A and B. The even numbered sections for this group, unlike group A, were also completed as a class. The slide/tape script for Lesson III is located in Appendix C.

Days 7-10. The fourth lesson which was entitled, "Capacity/Volume in SI Measurement," was administered to both experimental groups in the course of four days. During the first day, both groups viewed a common slide/tape dealing with SI units of capacity/volume. The slide/tape explained the units of volume most frequently used, the relationship that exists between each unit, the symbols of each unit, and the measuring scales used for each unit. The remaining three days were used to administer the treatment variables to the two instructional approaches. The maximum amount of time allotted for the treatment variables was forty minutes for grade four, ninety minutes for grade five, and ninety minutes for grade six. This treatment was to be administered over the remaining three days allotted for the lesson.

The procedures followed by each group were the same as those used during the fifth and sixth days of Lesson III (Appendixes D and E). The slide/tape script for Lesson IV is located in Appendix C.

Days 11-13. This period of time was utilized by the two instructional approaches to study Lesson V which dealt with a study of mass/weight. On the first day both experimental groups viewed a common slide/tape entitled, "Mass/Weight in SI Measurement." The two basic units of mass, kilogram and gram, were presented along with the symbols and measuring scales used for each. The last two days of the lesson were used to administer the treatment variables to the two instructional approaches. The maximum amount of time allotted for the treatment variables was thirty minutes for grade four, sixty minutes for grade five, and sixty minutes for grade six. This treatment was to be administered over the remaining two days of the lesson. The procedures followed by each group were the same as those used during the fifth and sixth days of

Lesson III (Appendixes D and E). The slide/tape script for Lesson V is located in Appendix C.

Day 14. The sixth and final lesson entitled, "Temperature in SI Measurement," was presented to both experimental groups through the use of a common slide/tape by the same title. This slide/tape was centered around the Celsius scale which is used to measure temperature in the International System of Units. Following the slide/tape presentation, the researcher provided the two instructional approaches with the treatment variables. The maximum amount of time allotted for the administration of the treatment variables was thirty minutes for grade four, thirty minutes for grade five, and thirty minutes for grade six.

The procedures followed by each group were the same as those used during the fifth and sixth days of Lesson III (Appendixes D and E). The slide/tape script for Lesson VI is located in Appendix C.

Administration of the Instruments

To ascertain whether or not any differences in attitude and achievement had occurred due to the experimental treatment, the researcher-prepared attitude scale, cognitive test and the laboratory and simulated sections of the achievement test were administered as a post measure. The attitude scale and cognitive test were administered on the fourteenth day of the treatment, whereas the laboratory and simulated sections of the achievement test were administered on the final two days of the experiment (Appendix F). Three weeks later, the same instruments were administered as tests of retention. The exception to this was the attitude scale which was not administered as a measure of retention. The attitude scale contained thirty items. The students were asked to provide one of three possible responses which were: (1) agree, (2) disagree, or (3) not sure. A copy of this scale is provided in Appendix I. The cognitive test contained thirty multiple-choice items. Each item was followed by five possible responses from which the student was to choose one. A copy of this instrument is located in Appendix J. Since there was a laboratory and a simulated section to the achievement test, each experimental group received the section related to their respective instructional approach during the first day and the remaining section of the test on the second day.

The laboratory section of the instrument contained twenty-seven multiple-choice items that required students to physically measure three-dimensional objects. Eighteen work stations were set up in the multi-purpose room of each school (Appendix F), and the measuring scales and objects needed for each section of the test were stored in a kit which was placed below each work station.

The simulated section of the achievement test also contained twenty-seven multiple-choice items which required students to record measurements when the measuring activities were simulated pictorially. Unlike the laboratory section, the simulated section of the achievement test was administered in the regular classroom.

The procedures utilized to administer both sections of the achievement test were identical for each instructional approach, regardless of the treatment to which the group had initially been assigned. Each student within a given instructional approach received one section of the instrument and a computer answer sheet. The general directions preceding each section of the instrument were designed to help students complete the information requested at the top of the answer sheets as well as to record their answers. The teachers read each test item aloud and allowed students sufficient time to complete the measuring activity. The teachers collected the instruments and answer sheets at the end of each testing session.

Scoring the Instruments

To expedite the scoring of all pre, post and retention measures, computer answer sheets were utilized throughout the study. After administering one of the evaluation instruments, the answer sheets were manually inspected for tears, bent papers, light marks and excessively smudged sheets, in an effort to assure the researcher that the machine used to score each paper would accept all of the answer sheets for processing.

Following the inspection, the answer sheets were optically scanned in the Testing Center of Central Missouri State University, Warrensburg, Missouri, and the raw scores were printed on the margin. In addition, the optical-scanning machine punched data cards to record the (1) instructional approach, (2) student identification number, (3) teacher identification number, (4) test type, (5) item responses, and (6) raw test scores. The data cards were then processed and analyzed through computer programs which are on file at the Computer Center of Central Missouri State University, Warrensburg, Missouri.

Summary

In early September of 1974, the Warrensburg R-VI Board of Education, principals of Reese, Ridgeview and Southeast Elementary Schools, and the twelve participating teachers from these schools were contacted to describe the proposed study and to solicit their cooperation. After approval was received from the teachers and principals, the participants were again contacted and were provided a detailed description of the study.

It was not possible to randomly assign students to treatments; therefore, the researcher accepted intact groups as scheduled and randomly assigned treatments to groups. To ascertain the initial difference that existed between the treatment groups, information was collected on the students' mental ability, attitude toward the

International System of Units and their prior knowledge of SI measurement. The mental ability of the students was assessed through administration of the Henmon-Nelson Test of Mental Ability (Form 1) to the entire fourth, fifth and sixth grade population of the Warrensburg R-VI Public Schools during the fall semester, 1974. The students' attitude toward SI measurement and their knowledge of the International System of Units was assessed through the use of researcher-designed instruments.

The study was initiated on April 4, 1975, with the administration of the attitude and cognitive measures in an effort to assess the students' feelings toward and prior knowledge of the International System of Units. All three grade levels then received the two treatments during the next three weeks. One experimental group received instruction by Approach A which had students physically measuring three-dimensional objects (laboratory activities), while the other experimental group received instruction by Approach B, which required them to learn the basic units of SI measurement through simulated activities. On the final two days of the experiment, a researcher-prepared attitude scale, cognitive instrument and laboratory and simulated sections of the achievement test were administered to each fourth, fifth and sixth grade student. Each experimental group was administered the section of the achievement test which related to their respective instructional approach during the first day of evaluation and the remaining section on the second day. Three weeks after administering the post measures, tests of retention were administered. Each answer sheet was manually inspected, machine scored, processed, and analyzed through the facilities of the Testing and Computer Centers of Central Missouri State University.

Chapter IV

MEASUREMENT AND ANALYSIS OF DATA

Chapter III described the preparation for the experiment, orientation meeting, initial status of groups, instructional procedures followed in conducting the experiment, administration of the instruments, and scoring of the instruments. This chapter presents the results of the data on the mental ability test, attitude scale, pretests, posttests, and tests of retention, by grade level, for the groups involved in the study. A description of the statistical analysis and the findings of the experiment are also reported in this chapter.

Method for Data Analysis

The purpose of this study as described in Chapter I was to ascertain what effect two instructional approaches to teaching the International System of Units would have upon the attitude, cognitive, achievement and retention of fourth, fifth and sixth grade students. The instructional approaches were: (1) Approach A (laboratory activity) provided instruction by having students physically measure three-dimensional objects with metric scales, and (2) Approach B (simulation activity) provided instruction by having students identify measurements from pictures of two-dimensional objects along side of which metric scales had been printed. The effect of the two sections of the achievement test on the initial achievement and retention of the International System of Units was also investigated.

The relative effects of all the data were measured by the scores of scales, pretests, posttests, and tests of retention which were obtained from the eighty-three fourth grade, eighty-two fifth grade and eighty-seven sixth grade students participating in the study. The score of each student is recorded in Appendix A, by grade level.

Since this study was composed of naturally assembled intact classes, it became evident that the initial status of the experimental groups could be different. Therefore, due to the nature of the classes, the researcher analyzed the data resulting from administration of the attitude scale, cognitive test, achievement test and tests of retention by analysis of covariance through multiple regression.

As stated in Chapter I, the assumption of homogeneity of regression coefficients is assumed to be true when adjustments are made for covariates.[1] Therefore, it is important for one to first establish that the regression coefficients in each group are the same before testing in order to ascertain whether or not significant differences exist between the treatment groups.

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[1] Fred Kerlinger and Elazor Pedhazur, Multiple Regression in Behavioral Research (New York: Holt, Rinehart and Winston, Inc., 1973), p. 267.

Due to a definite lack of experimental research data to support SI measurement, the .05 level of confidence has been accepted as the standard confidence level for this study.

Testing for Homogeneity of Regression Coefficients On Posttest Data

The student scores from the researcher-prepared attitude scale (Appendix I), cognitive test (Appendix J), and the simulated and laboratory achievement tests (Appendix F) were evaluated and the resulting data were analyzed for homogeneity of regression coefficients. This procedure was utilized to ascertain whether or not the effect of attitude toward the International System of Units, prior knowledge of the International System of Units and mental ability were different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B. Thus, the null hypotheses which follow were subjected to analysis at each grade level. All hypotheses will be subjected to analysis at a single grade level before moving to another hypothesis, rather than analyzing each individual hypothesis at each grade level. This will allow for a comparison of all hypotheses at a given grade level prior to an analysis of selected hypotheses for combined grades.

Fourth Grade

Attitude. The first hypothesis which was subjected to analysis was:

> Ho_{1-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the attitude scale on the mental ability scores, does not significantly improve the prediction of the scores of the attitude scale over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in attitude, the multiple regression procedure was used to compare the regression coefficients of all the fourth grade students in Approaches A and B. Table II is used to illustrate the separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0007 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the post attitude scale. The "F" ratio associated with this increment, as shown in Table II, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{1-4}) was accepted.

Cognitive. The second hypothesis which was subjected to analysis was:

TABLE II

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON POSTTEST DATA OF FOURTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Attitude $R^2_{1,7,10,23,24}-R^2_{1,5,7,10}$	.0007	1	.0007	.07
Error Term $1-R^2_{1,7,10,23,24}$	.7214	77	.0094	
Cognitive $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0054	1	.0054	1.42
Error Term $1-R^2_{1,7,23,24}$	.2984	78	.0038	
Simulated Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0011	1	.0011	.14
Error Term $1-R^2_{1,7,23,24}$	.6008	78	.0077	
Laboratory Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0001	1	.0001	.01
Error Term $1-R^2_{1,7,23,24}$	.6495	78	.0083	

$R^2_{1,7,23,24}$ or $R^2_{1,7,10,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,5,7}$ or $R^2_{1,5,7,10}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = Approach A-Approach B; 5 = combined mental ability; 7 = achievement pretest; 10 = attitude pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated

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F-ratio required for significance at the .05 level is 3.96 for both 1 and 78 degrees of freedom and 1 and 77 degrees of freedom.

*Significance at the .05 level.

Ho2-4: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the cognitive achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in the knowledge students had acquired of the International System of Units as measured by the cognitive test, the multiple regression procedure was used to compare the regression coefficients of all fourth grade students in Approaches A and B. Table II (page 86) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0054 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive posttest. The "F" ratio associated with this increment, as shown in Table II (page 86), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{2-4}) was accepted.

Achievement--Simulated. The hypothesis associated with simulated achievement was:

Ho_{3-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in simulated achievement, the multiple regression procedure was again used to compare the regression coefficients of all students in Approaches A and B. Table II (page 86) is also used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0011 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement posttests. The "F" ratio associated with this increment, as shown in Table II (page 86), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{3-4}) was accepted.

Achievement--Laboratory. The hypothesis associated with laboratory achievement was:

Ho_{4-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the achievement test on the mental ability scores, does not

> significantly improve the prediction of the scores of the laboratory section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four.

A test for a significant difference in laboratory achievement using the multiple regression procedure was also used. Table II (page 86) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

The analysis yielded an increment of .0001 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement posttest. The "F" ratio associated with this increment, also shown in Table II (page 86), was found to be no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{4-4}) was accepted.

Testing the Effects of Approaches
On Posttest Data

After an analysis of the homogeneity of regression coefficients on the posttest data, the researcher then tested the effects of the approaches on the data.

Fourth Grade

Attitude. Acceptance of the null hypothesis (Ho_{1-4}) revealed that the effect of attitude toward the

International System of Units, knowledge of the International System of Units, and mental ability were in fact the same for all students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significance differences between approaches utilizing the following hypothesis:

> Ho_{5-4}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units, and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the attitude scores of all students who were exposed to Approaches A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The attitude means for students exposed to Approaches A and B were 12.80 and 14.26 respectively, as reported in Table III. The differences between the attitude means for the students were tested and found to be no greater than could be expected by chance, as is shown in Table IV.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{5-4}) was accepted.

TABLE III

MEANS AND STANDARD DEVIATIONS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
Attitude	12.80	6.28	14.26	8.76	13.54
Cognitive	12.37	4.39	17.10	6.23	14.76

II. Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Means
Attitude Pretest	10.17	4.06	10.52	3.76	10.35
Cognitive Pretest	7.05	2.95	9.43	3.16	8.25
Mental Ability	104.61	13.84	114.38	15.22	109.55

TABLE IV

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF FOURTH GRADE STUDENT

Source	Proportion of Variance (R^2)	df
Covariate $R^2_{5,7,10}$	.2778	
Attitude (after adjustment) $R^2_{5,7,10,21}-R^2_{5,7,10}$	.0001	1
Error: Subjects x Attitude Within Approaches $1-R^2_{5,7,10,21}$	.7721	78
Covariate (after adjustment) $R^2_{5,7}$	.6901	
Cognitive (after adjustment) $R^2_{5,7,21}-R^2_{5,7}$	.0066	1
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.3033	79

Vector 5 = mental ability; 7 = achievement pretest; 10 = attitude prete
______ A - approach B

F-ratio required for significance at the .05 level is 3.96 for
degrees of freedom, and 1 and 78 degrees of freedom.

*Significance at .05 level of significance.

Cognitive. Acceptance of null hypothesis (Ho_{2-4}) allowed the researcher to examine the data for significant differences between approaches utilizing the following hypothesis:

> Ho_{6-4}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the cognitive scores of students who were exposed to Approach A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive means for students exposed to Approaches A and B were 12.37 and 17.10 respectively, as reported in Table III (page 91). The differences between the cognitive means were tested and found to be no greater than could be expected by chance as is shown in Table IV (page 92).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{6-4}) was accepted.

Achievement. Acceptance of the null hypothesis (Ho_{3-4}) and (Ho_{4-4}) revealed that the effect of mental ability was in fact the same for students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significant differences between approaches and test types utilizing the following hypotheses:

Ho_{7-4}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade four.

Ho_{8-4}: No significant difference exists between the scores students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade four.

Ho_{9-4}: No significant interaction exists between the scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the achievement scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined achievement means for students exposed to Approaches A and B, regardless of test type, were 6.87 and 8.09 respectively, as reported in Table V. The differences between the combined achievement means for students were tested and found to be no greater than could be expected by chance as is shown in Table VI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{7-4}) was accepted.

TABLE V

MEANS AND STANDARD DEVIATIONS OF POSTTEST ACHIEVEMENT SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I.	Test Type	Approach A		Approach B		Mean Totals
		Mean	S.D.	Mean	S.D.	
	Simulated Section	7.49	2.20	8.55	1.33	8.02
	Laboratory Section	6.24	1.72	7.62	1.75	6.94
	Totals	6.87		8.09		

II.	Covariates	Approach A		Approach B		Grand Means
		Mean	S.D.	Mean	S.D.	
	Cognitive Pretest	7.05	2.95	9.43	3.16	8.25
	Mental Ability	104.61	13.84	114.38	15.22	109.55

TABLE VI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ACHIEVEMENT SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.3344			
Approaches (after adjustment) $R^2_{5,7,21} - R^2_{5,7}$	.0101	1	.0101	2.02
Test Type (after adjustment) $R^2_{5,7,22} - R^2_{5,7}$	.0770	1	.0770	35.00*
Approaches x Test Type (after adjustment) $R^2_{5,7,23} - R^2_{5,7}$	.0013	1	.0013	.59
Error:				
Subjects Within Approaches $R^2_{5,7,26 \text{ to } 108} - R^2_{5,7,21}$	.4029	81	.0050	
Subjects x Test Types Within Approaches $1 - R^2_{5,7,22,23,26 \text{ to } 108}$	.1740	79	.0022	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B; 22 = test type; 23 = approach x test type; 26 to 108 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 81 degrees of freedom and 1 and 79 degrees of freedom.

*Significance at the .05 level of significance.

In an effort to ascertain whether there were significant differences between the achievement scores of students on the laboratory section of the achievement test and their scores on the simulated section of the achievement test, the analysis of covariance through multiple regression statistical procedure was again utilized. The combined means for students on the laboratory section as well as the simulated section of the achievement test, regardless of instructional approaches, were 8.02 and 6.94 respectively, as reported in Table V (page 95). There was a significant difference in achievement scores of students which favored the simulated section of the achievement test. As reported in Table VI (page 96), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{8-4}) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for students, the analysis of covariance through multiple regression statistical procedure was again utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types for students, as is shown in Table VI (page 96).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{9-4}) was accepted.

Testing for Homogeneity of Regression Coefficients On Test of Retention Data

The student scores from the researcher-prepared cognitive test of retention (Appendix J) and the achievement tests of retention (Appendix F) were evaluated and the resulting data were analyzed for homogeneity of regression coefficients. This procedure was utilized to ascertain whether the effect of prior knowledge of the International System of Units and mental ability were different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B.

Fourth Grade

Cognitive. The following hypothesis was used to assess the amount of cognitive information which the students had retained:

> Ho_{10-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive retention test on mental ability scores, does not significantly improve the prediction of the scores of the cognitive retention test over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in retention, the multiple regression procedure was utilized to compare the regression coefficients of all the students in Approaches A and B. Table VII is used to illustrate the proportion of variance accounted for by using separately

TABLE VII

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON RETENTION TEST DATA OF FOURTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Cognitive $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0071	1	.0071	1.36
Error Term $1-R^2_{1,7,23,24}$	.4065	78	.0052	
Simulated Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0002	1	.0002	.02
Error Term $1-R^2_{1,7,23,24}$	.6734	78	.0086	
Laboratory Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0001	1	.0001	.01
Error Term $1-R^2_{1,7,23,24}$	.6887	78	.0088	

$R^2_{1,7,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,5,7}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated

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F-ratio required for significance at the .05 level is 3.96 for 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0071 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive test of retention. The "F" ratio associated with the increment, as shown in Table VII, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{10-4}) was accepted.

Achievement--Simulated. The null hypothesis associated with retention on the simulated section of the achievement test was:

> Ho_{11-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in retention on the simulated section of the achievement test, the multiple regression procedure was used to compare the regression coefficients of all the students in Approaches A and B. Table VII (page 99), is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0002 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement test of retention. The "F" ratio associated with the increment, as shown in Table VII (page 99) was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{11-4}) was accepted.

Achievement--Laboratory. The hypothesis associated with retention on the laboratory section of the achievement test was:

> Ho_{12-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in retention on the laboratory section of the achievement test, the multiple regression procedure was again used. Table VII (page 99) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0001 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement test of retention. The "F" ratio associated with this increment, also shown in Table VII (page 99), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{12}-4) was accepted.

Testing the Effects of Approaches On Retention Test Data

After an analysis of the homogeneity of regression coefficients on the retention test data, the researcher then tested the effects of the approaches on the data.

Fourth Grade

Cognitive. Due to the acceptance of the null hypothesis (Ho_{10}-4) which revealed that the effect of mental ability and prior knowledge of the International System of Units was in fact the same for students receiving instruction by Approach A and B, the researcher then examined the data for significant differences between approaches utilizing the following hypothesis:

> Ho_{13}-4: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the cognitive retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive retention means for students exposed to Approaches A and B, regardless of test type, were 12.80 and 16.10 respectively, as reported in Table VIII. The differences between the cognitive retention means were tested and found to be no greater than could be expected by chance, as is shown in Table IX.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{13}-4) was accepted.

Achievement. Due to acceptance of hypotheses (Ho_{11}-4) and (Ho_{12}-4) which tested for homogeneity of regression coefficients, the researcher was able to ascertain the effects of: (1) Approaches A and B on retention, (2) simulated and laboratory test types on retention, and (3) the interaction of these two factors on retention.

Stated in the null form for purposes of statistical treatment, the following retention hypotheses were tested:

TABLE VIII

MEANS AND STANDARD DEVIATIONS OF COGNITIVE RETENTION TEST SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A Mean	 S.D.	Approach B Mean	 S.D.	Mean Totals
Cognitive	12.80	4.15	16.10	5.09	14.47

II. Covariates	Approach A Mean	 S.D.	Approach B Mean	 S.D.	Grand Mean
Cognitive Pretest	7.05	2.95	9.43	3.16	8.25
Mental Ability	104.61	13.84	114.38	15.22	109.55

Ho_{14}-4: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the test of retention after initial knowledge of the International System of Units and mental ability are held constant for grade four.

Ho_{15}-4: No significant difference exists between the scores students received on the laboratory section and the simulated section of the test of retention, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade four.

TABLE IX

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF COGNITIVE RETENTION TEST SCORES OF FOURTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.5863			
Cognitive $R^2_{5,7,21}-R^2_{5,7}$	.0012	1	.0012	.23
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.4125	79	.0052	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.96 for 1 and 79 degrees of freedom.

*Significance at the .05 level of significance.

> Ho_{16-4}: No significant interaction exists between the retention scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined retention means for students exposed to Approaches A and B, regardless of test type, were 7.17 and 8.01 respectively, as reported in Table X. The differences between the combined retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{14-4}) was accepted.

In an effort to ascertain whether there were significant differences between the retention scores of students on the simulated section of the test of retention and their scores on the laboratory section of the test of retention, the analysis of covariance through multiple regression statistical procedure was utilized. The combined means for students on the simulated section as well as the laboratory section of the achievement test,

TABLE X

MEANS AND STANDARD DEVIATIONS OF RETENTION TEST SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I.	Source	Approach A Mean	 S.D.	Approach B Mean	 S.D.	Mean Totals
	Simulated Section Retention	7.51	1.95	8.07	2.24	7.80
	Laboratory Section Retention	6.83	1.64	7.95	1.57	7.40
	Totals	7.17		8.01		

II.	Covariates	Approach A Mean	 S.D.	Approach B Mean	 S.D.	Grand Mean
	Cognitive Pretest	7.05	2.95	9.43	3.16	8.25
	Mental Ability	104.61	13.84	114.38	15.22	109.55

regardless of instructional approaches, were 7.80 and 7.40 respectively, as reported in Table X. There was a significant difference in retention scores of students which favored the simulated section of the retention test.

TABLE XI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF RETENTION TEST SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate				
$R^2_{5,7}$	.3001			
Approaches (after adjustment)				
$R^2_{5,7,21}-R^2_{5,7}$	.0004	1	.0004	.06
Test Type (after adjustment)				
$R^2_{5,7,22}-R^2_{5,7}$	.0106	1	.0106	4.61*
Approaches x Test Type (after adjustment)				
$R^2_{5,7,23}-R^2_{5,7}$	.0051	1	.0051	2.22
Error:				
Subjects Within Approaches				
$R^2_{5,7,26 \text{ to } 108}-R^2_{5,7,21}$	.4986	81	.0062	
Subjects x Test Types Within Approaches				
$1-R^2_{5,7,22,23,26 \text{ to } 108}$	.1850	79	.0023	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-Approach B; 22 = test type; 23 = approach x test type; 26 to 108 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 81 degrees of freedom and 1 and 79 degrees of freedom.

*Significance at the .05 level.

As reported in Table XI (page 108), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho15-4) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for students, the analysis of covariance through multiple regression statistical procedure was again utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types, as is shown in Table XI (page 108).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho16-4) was accepted.

Upon completion of the analysis of all the data for grade four, the researcher then proceeded to apply the same statistical procedure to the fifth grade data as had been applied to the fourth grade data.

Testing for Homogeneity of Regression Coefficients On Posttest Data

Fifth Grade

Attitude. The first hypothesis which was subjected to analysis was:

Ho_{1-5}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the attitude scale on the mental ability scores, does not significantly improve the prediction of the scores of the attitude scale over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in attitude, the multiple regression procedure was used to compare the regression coefficients of all the fourth grade students in Approaches A and B. Table XII is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0004 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the post attitude scale. The "F" ratio associated with this increment, as shown in Table XII, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{1-5}) was accepted.

Cognitive. The second hypothesis which was subjected to analysis was:

TABLE XII

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON POSTTEST DATA OF FIFTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Attitude $R^2_{1,7,10,23,24} - R^2_{1,5,7,10}$	.0004	1	.0004	.05
Error Term $1 - R^2_{1,7,10,23,24}$	.6304	77	.0082	
Cognitive $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0076	1	.0076	1.62
Error Term $1 - R^2_{1,7,23,24}$	.3679	78	.0047	
Simulated Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0002	1	.0002	.04
Error Term $1 - R^2_{1,7,23,24}$	.4232	78	.0054	
Laboratory Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.004	1	.004	.73
Error Term $1 - R^2_{1,7,23,24}$	.4283	78	.0055	

$R^2_{1,7,23,24}$ or $R^2_{1,7,10,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,7,5}$ or $R^2_{1,7,5,10}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 10 = attitude pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 78 degrees of freedom and 1 and 77 degrees of freedom.

*Significance at the .05 level of significance.

Ho_2-5: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the cognitive achievement test over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in the knowledge students had acquired of the International System of Units as measured by the cognitive test, the multiple regression procedure was used to compare the regression coefficients of all fifth grade students in Approaches A and B. Table XII (page 111) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0076 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive posttest. The "F" ratio associated with this increment, as shown in Table XII (page 111), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_2-5) was accepted.

Achievement--Simulated. The hypothesis associated with simulated achievement was:

Ho3-5: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in simulated achievement, the multiple regression procedure was again used to compare the regression coefficients of all students in Approaches A and B. Table XII (page 111) is also used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0002 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement posttests. The "F" ratio associated with this increment, as shown in Table XII (page 111), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho3-5) was accepted.

Achievement--Laboratory. The hypothesis associated with laboratory achievement was:

Ho_4-5: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade five.

A test for a significant difference in laboratory achievement using the multiple regression procedure was also used. Table XII (page 111) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

The analysis yielded an increment of .004 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement posttest. The "F" ratio associated with this increment, also shown in Table XII (page 111), was found to be no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_4-5) was accepted.

Testing the Effects of Approaches On Posttest Data

After an analysis of the homogeneity of regression coefficients on the posttest data, the researcher then tested the effects of the approaches on the data.

Fifth Grade

Attitude. Acceptance of the null hypothesis (Ho_{1-5}) revealed that the effect of attitude toward the International System of Units, knowledge of the International System of Units, and mental ability were in fact the same for all students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significance differences between approaches utilizing the following hypothesis:

> Ho_{5-5}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the attitude scores of all students who were exposed to Approaches A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The attitude means for students exposed to Approaches A and B were 16.71 and 15.05 respectively, as reported in Table XIII. The differences between the attitude means for the students were tested and found to be no greater than could be expected by chance, as is shown in Table XIV.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{5-5}) was accepted.

TABLE XIII

MEANS AND STANDARD DEVIATIONS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I.	Source	Approach A		Approach B		Mean Totals
		Mean	S.D.	Mean	S.D.	
	Attitude	16.71	7.36	15.05	8.80	15.88
	Cognitive	15.37	5.74	14.24	6.65	14.80

II.	Covariates	Approach A		Approach B		Grand Mean
		Mean	S.D.	Mean	S.D.	
	Attitude Pretest	12.20	3.45	11.54	3.42	11.87
	Cognitive Pretest	9.29	3.60	10.20	4.09	9.74
	Mental Ability	112.27	15.17	108.24	15.65	110.26

TABLE XIV

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF FIFTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7,10}$	.3658			
Attitude (after adjustment) $R^2_{5,7,10,21}-R^2_{5,7,10}$	.0038	1	.0038	.46
Error: Subjects x Attitude Within Approaches $1-R^2_{5,7,10,21}$	.6304	77	.0082	
Covariate $R^2_{5,7}$	.6210			
Cognitive (after adjustment) $R^2_{5,7,21}-R^2_{5,7}$	.0035	1	.0035	.73
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.3755	78	.0038	

Vector 5 = mental ability; 7 = achievement pretest; 10 = attitude pretest; 21 = approach A-approach B.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 78 degrees of freedom and 1 and 77 degrees of freedom.

*Significance at .05 level of significance.

Cognitive. Acceptance of null hypothesis (Ho_{2-5}) allowed the researcher to examine the data for significant differences between approaches utilizing the following hypothesis:

> Ho_{6-5}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the cognitive scores of students who were exposed to Approach A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive means for students exposed to Approaches A and B were 15.37 and 14.24 respectively, as reported in Table XIII (page 116). The differences between the cognitive means were tested and found to be no greater than could be expected by chance as is shown in Table XIV (page 117).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{6-5}) was accepted.

Achievement. Acceptance of the null hypotheses (Ho_{3-5}) and (Ho_{4-5}) revealed that the effect of mental ability was in fact the same for students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significant differences between approaches and test types utilizing the following hypotheses:

Ho_{7-5}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade five.

Ho_{8-5}: No significant difference exists between the scores students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade five.

Ho_{9-5}: No significant interaction exists between the scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the achievement scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined achievement means for students exposed to Approaches A and B, regardless of test type, were 21.94 and 20.77 respectively, as reported in Table XV. The differences between the combined achievement means for students were tested and found to be no greater than could be expected by chance as is shown in Table XVI.

TABLE XV

MEANS AND STANDARD DEVIATIONS OF POSTTEST ACHIEVEMENT SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Test Type	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Simulated Section	23.15	4.17	21.95	4.58	22.55
Laboratory Section	20.73	5.26	19.59	5.07	20.16
Totals	21.94		20.77		

II. Covariates	Approach A		Approach B		Grand Means
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	9.29	3.60	10.20	4.09	9.74
Mental Ability	112.27	15.17	108.24	15.65	110.26

TABLE XVI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ACHIEVEMENT SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	f
Covariate				
$R^2_{5,7}$	.5329			
Approaches (after adjustment)				
$R^2_{5,7,21}-R^2_{5,7}$	.0017	1	.0017	.47
Test Type (after adjustment)				
$R^2_{5,7,22}-R^2_{5,7}$	.0578	1	.0578	38.53*
Approaches x Test Type (after adjustment)				
$R^2_{5,7,23}-R^2_{5,7}$	.0000	1	.0000	.00
Error:				
Subjects Within Approaches				
$R^2_{5,7,26 \text{ to } 105}-R^2_{5,7,21}$	.2898	80	.0036	
Subjects x Test Types Within Approaches				
$1-R^2_{5,7,22,23,26 \text{ to } 105}$	.1177	78	.0015	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B; 22 = test type; 23 = approach x test type; 26 to 105 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 80 degrees of freedom and 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{7-5}) was accepted.

In an effort to ascertain whether there were significant differences between the achievement scores of students on the laboratory section of the achievement test and their scores on the simulated section of the achievement test, the analysis of covariance through multiple regression statistical procedure was again utilized. The combined means for students on the laboratory section as well as the simulated section of the achievement test, regardless of instructional approaches, were 22.55 and 20.16 respectively, as reported in Table XV (page 120). There was a significant difference in achievement scores of students which favored the simulated section of the achievement test. As reported in Table XVI (page 121), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{8-5}) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for students, the analysis of covariance through multiple regression statistical procedure was again utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types for students, as is shown in Table XVI (page 121).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{9-5}) was accepted.

Testing for Homogeneity of Regression Coefficients On Test of Retention Data

The student scores from the researcher-prepared cognitive test of retention (Appendix J) and the achievement tests of retention (Appendix F) were evaluated and the resulting data were analyzed for homogeneity of regression coefficients. This procedure was utilized to ascertain whether the effect of prior knowledge of the International System of Units and mental ability were different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B.

Fifth Grade

Cognitive. The following hypothesis was used to assess the amount of cognitive information which the students had retained:

> Ho_{10-5}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive retention test on mental ability scores, does not significantly improve the prediction of the scores of the cognitive retention test over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in retention, the multiple regression procedure was utilized to compare the regression coefficients of all the students in Approaches A and B. Table XVII is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive test of retention. The "F" ratio associated with the increment, as shown in Table XVII, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{10-5}) was accepted.

Achievement--Simulated. The null hypothesis associated with retention on the simulated section of the achievement test was:

> Ho_{11-5}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in retention on the simulated section of the achievement test, the multiple regression procedure was used to compare the regression coefficients of all the students in Approaches

TABLE XVII

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON RETENTION TEST DATA OF FIFTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Cognitive $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0000	1	.0000	.00
Error Term $1 - R^2_{1,7,23,24}$	.4212	78	.0054	
Simulated Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0008	1	.0008	.13
Error Term $1 - R^2_{1,7,23,24}$	.4738	78	.0061	
Laboratory Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0284	1	.0284	3.94
Error Term $1 - R^2_{1,7,23,24}$	.5654	78	.0072	

$R^2_{1,7,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,5,7}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 23 = mental ability-laboratory; 23 = mental ability-simulated.

F-ratio required for significance at the .05 level is 3.96 for 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

TABLE XVIII

MEANS AND STANDARD DEVIATIONS OF COGNITIVE RETENTION TEST SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Cognitive	15.44	4.97	14.59	5.68	15.01

II. Covariates	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	9.29	3.60	10.20	4.09	9.74
Mental Ability	112.27	15.17	108.24	15.65	110.26

A and B. Table XVII (page 125) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0008 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement test of retention. The "F" ratio associated with the increment, as shown in Table XVII (page 125) was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{11-5}) was accepted.

Achievement--Laboratory. The hypothesis associated with retention on the laboratory section of the achievement test was:

> Ho_{12-5}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in retention on the laboratory section of the achievement test, the multiple regression procedure was again used. Table XVII (page 125) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0284 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement test of retention. The "F" ratio associated with this increment, also shown in Table XVII (page 125), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{12-5}) was accepted.

Testing the Effects of Approaches On Retention Test Data

After an analysis of the homogeneity of regression coefficients on the retention test data, the researcher then tested the effects of the approaches on the data.

Fifth Grade

Cognitive. Due to the acceptance of the null hypothesis (Ho_{10-5}) which revealed that the effect of mental ability and prior knowledge of the International System of Units was in fact the same for students receiving instruction by Approach A and B, the researcher then examined the data for significant differences between approaches utilizing the following hypothesis:

> Ho_{13-5}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the cognitive retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive retention means for students exposed to Approaches A and B, regardless of test type, were 15.44 and 14.59 respectively, as reported in Table XVIII (page 126). The differences between the cognitive retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XIX.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{13-5}) was accepted.

Achievement. Due to acceptance of hypotheses (Ho_{11-5}) and (Ho_{12-5}) which tested for homogeneity of regression coefficients, the researcher was able to ascertain the effects of: (1) Approaches A and B on retention, (2) simulated and laboratory test types on retention, and (3) the interaction of these two factors on retention.

Stated in the null form for purposes of statistical treatment, the following retention hypotheses were tested:

Ho_{14-5}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the test of retention after initial knowledge of the International System of Units and mental ability are held constant for grade five.

Ho_{15-5}: No significant difference exists between the scores students received on the laboratory section and the simulated section of the test of retention, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade five.

TABLE XIX

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF COGNITIVE RETENTION TEST SCORES OF FIFTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.5741			
Cognitive $R^2_{5,7,21}-R^2_{5,7}$	.0047	1	.0047	.87
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.4212	78	.0054	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.96 for 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

Ho_{16}-5: No significant interaction exists between the retention scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined retention means for students exposed to Approaches A and B, regardless of test type, were 23.45 and 21.58 respectively, as reported in Table XX. The differences between the combined retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XXI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{14}-5) was accepted.

In an effort to ascertain whether there were significant differences between the retention scores of students on the simulated section of the test of retention and their scores on the laboratory section of the test of retention, the analysis of covariance through multiple regression statistical procedure was utilized. The combined means for students on the simulated section as well as the laboratory section of the achievement test, regardless of instructional approaches, were 23.21 and 21.82 respectively, as reported in Table XX. There was a

TABLE XX

MEANS AND STANDARD DEVIATIONS OF RETENTION TEST SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I.	Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
	Simulated Section Retention	24.15	4.15	22.27	4.54	23.21
	Laboratory Section Retention	22.76	3.50	20.88	4.59	21.82
	Totals	23.45		21.58		

II.	Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Mean
	Covariate Pretest	9.29	3.60	10.20	4.09	9.74
	Mental Ability	112.27	15.17	108.24	15.65	110.26

TABLE XXI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF RETENTION TEST SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.4332			
Approaches (after adjustment) $R^2_{5,7,21}-R^2_{5,7}$	.0194	1	.0194	4.41*
Test Type (after adjustment) $R^2_{5,7,22}-R^2_{5,7}$	.0253	1	.0253	12.05*
Approaches x Test Type (after adjustment) $R^2_{5,7,23}-R^2_{5,7}$	.0000	1	.0000	.00
Error: Subjects Within Approaches $R^2_{5,7,26 \text{ to } 105}-R^2_{5,7,21}$	.3547	80	.0044	
Subjects x Test Types Within Approaches $1-R^2_{5,7,22,23,26 \text{ to } 105}$	.1638	78	.0021	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B; 22 = test type; 23 = approach x test type; 26 to 105 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 80 degrees of freedom and 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

significant difference in retention scores of students which favored the simulated section of the retention test. As reported in Table XXI (page 133), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{15-5}) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for students, the analysis of covariance through multiple regression statistical procedure was again utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types, as is shown in Table XXI (page 133).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{16-5}) was accepted.

Upon completion of the analysis of all the data for grade five, the researcher then proceeded to apply the same statistical procedures to the sixth grade data as had been applied to the fourth and fifth grade data.

Test for Homogeneity of Regression Coefficients On Posttest Data

Sixth Grade

Attitude. The first hypothesis which was subjected to analysis was:

Ho_{1-6}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the attitude scale on the mental ability scores, does not significantly improve the prediction of the scores of the attitude scale over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in attitude, the multiple regression procedure was used to compare two regression coefficients of all the sixth grade students in Approaches A and B. Table XXII is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0265 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the post attitude scale. The "F" ratio associated with this increment, as shown in Table XXII, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{1-6}) was accepted.

Cognitive. The second hypothesis which was subjected to analysis was:

TABLE XXII

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON POSTTEST DATA OF SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Attitude $R^2_{1,7,10,23,24} - R^2_{1,5,7,10}$	.0265	1	.0265	3.92
Error Term $1 - R^2_{1,7,10,23,24}$	.5475	81	.0068	
Cognitive $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0199	1	.0199	3.49
Error Term $1 - R^2_{1,7,23,24}$	.4695	82	.0057	
Simulated Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0022	1	.0022	.26
Error Term $1 - R^2_{1,7,23,24}$	.7032	82	.0086	
Laboratory Section $R^2_{1,7,23,24} - R^2_{1,7,5}$	.0492	1	.0492	5.79*
Error Term $1 - R^2_{1,7,23,24}$	.6985	82	.0085	

$R^2_{1,7,23,24}$ or $R^2_{1,7,10,23,24}$ = proportion of variance accounted for by using regression coefficients for each group

$R^2_{1,5,7}$ or $R^2_{1,5,7,10}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 10 = attitude pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 82 degrees of freedom and 1 and 81 degrees of freedom.

*Significance at the .05 level of significance.

Ho_2-6: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the cognitive achievement test over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in the knowledge students had acquired of the International System of Units as measured by the cognitive test, the multiple regression procedure was used to compare the regression coefficients of all sixth grade students in Approaches A and B. Table XXII (page 136) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0199 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive posttest. The "F" ratio associated with this increment, as shown in Table XXII (page 136), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_2-6) was accepted.

Achievement--Simulated. The hypothesis associated with simulated achievement was:

Ho$_3$-6: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in simulated achievement the multiple regression procedure was again used to compare the regression coefficients for all students in Approaches A and B. Table XXII (page 136) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0022 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement posttests. The "F" ratio associated with this increment, as shown in Table XXII (page 136), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho$_3$-5) was accepted.

Achievement--Laboratory. The hypothesis associated with laboratory achievement was:

Ho_4-6: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade six.

A test for a significant difference in laboratory achievement using the multiple regression procedure was also used. Table XXII (page 136) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

The analysis yielded an increment of .0492 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement posttests. The "F" ratio associated with this increment, also shown in Table XXII (page 136), was found to be greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_4-6) was rejected.

Testing the Effects of Approaches On Posttest Data

Sixth Grade

Attitude. Acceptance of the null hypothesis (Ho_1-6) revealed that the effect of attitude toward the International System of Units, knowledge of the International

System of Units, and mental ability were in fact the same for all students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significant differences between approaches utilizing the following hypothesis:

> $Ho_{5\text{-}6}$: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units and mental ability are held constant for grade six.

In an effort to ascertain whether there were significant differences between the attitude scores of students who were exposed to Approaches A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The attitude means for students exposed to Approach A and B were 19.37 and 12.76 respectively, as reported in Table XXIII The differences between the attitude means were tested and found to be much greater than could be expected by chance as is shown in Table XXIV. The significance was in favor of Approach A, the laboratory approach.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis ($Ho_{5\text{-}6}$) was rejected.

Cognitive. Acceptance of null hypothesis ($Ho_{2\text{-}6}$) allowed the researcher to examine the data for significant

TABLE XXIII

MEANS AND STANDARD DEVIATIONS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Attitude	19.37	8.09	12.76	9.01	15.88
Cognitive	17.41	5.11	16.35	6.19	16.85

II. Covariates	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Attitude Pretest	10.15	3.17	11.43	3.56	10.83
Cognitive Pretest	8.39	2.90	10.87	4.46	9.70
Mental Ability	108.41	12.87	101.61	16.06	104.81

TABLE XXIV

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7,10}$	.2327			
Attitude (after adjustment) $R^2_{5,7,10,21} - R^2_{5,7,10}$	.1914	1	.1914	27.34*
Error: Subjects x Attitude Within Approaches $1 - R^2_{5,7,10,21}$	.5759	82	.0070	
Covariate (after adjustment) $R^2_{5,7}$	.4969			
Cognitive (after adjustment) $R^2_{5,7,21} - R^2_{5,7}$	.0137	1	.0137	2.32
Error: Subjects x Cognitive Within Approaches $1 - R^2_{5,7,21}$	.4894	83	.0059	

Vector 5 = mental ability; 7 = achievement pretest; 10 = attitude pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.96 for both 1 and 83 degrees of freedom and 1 and 82 degrees of freedom.

*Significance at the .05 level of significance.

differences between approaches utilizing the following hypothesis:

> Ho_{6}-6: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade six.

In an effort to ascertain whether there were significant differences between the cognitive scores of students who were exposed to Approach A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive means for students exposed to Approaches A and B were 17.41 and 16.35 respectively, as reported in Table XXIII (page 141). The difference between the cognitive means were tested and found to be no greater than could be expected by chance as is shown in Table XXIV (page 142).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{6}-6) was accepted.

Achievement. Rejection of the null hypothesis (Ho_{4}-6) revealed that the effect of knowledge of the International System of Units and mental ability were different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B. This necessitated the formulation of alternative hypotheses, three for high ability students and three for low ability students, which then took the place of the original hypotheses (Ho_{7-6})-(Ho_{9-6}), which could no longer be used due to the findings in hypothesis (Ho_{4-6}). These new hypotheses were designed to ascertain the effect of: (1) Approaches A and B on achievement, (2) laboratory and simulated test types on achievement, and (3) the interaction of these two factors on achievement.

The high ability group consisted of students in the upper 40 percent of a distribution of mental ability scores of all sixth grade students participating in the study, and the low ability group consisted of students having scores in the lower 40 percent of all sixth grade student mental ability scores. As a result of this process, all of the sixth grade students who scored 112 or above on the Henmon-Nelson Test of Mental Ability (Form 1) were placed in the high ability group, while students who scored 102 or below on the same instrument were placed in the low ability group. The mental ability scores are located in Appendix A.

Informational achievement of high ability students. Stated in the null form for purposes of statistical treatment, the following alternative hypotheses for high ability sixth grade students were tested:

> Ho_{7-6-H}: No significant difference exists between high ability students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units is held constant.

Ho8-6-H: No significant difference exists between the scores high ability students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units is held constant.

Ho9-6-H: No significant interaction exists between the scores high ability students received on instructional approaches and test types, after initial knowledge of the International System of Units is held constant.

In an effort to ascertain whether there were significant differences between the achievement scores of high ability sixth grade students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined achievement means for high ability students exposed to Approaches A and B, regardless of test types, were 24.93 and 24.61 respectively, as reported in Table XXV. The differences between the combined achievement means for high ability sixth grade students were tested and found to be no greater than could be expected by chance as is shown in Table XXVI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho7-6-H) was accepted.

In an effort to ascertain whether there were significant differences between the achievement scores of high ability students on the laboratory section of the achievement tests and their scores on the simulated section

TABLE XXV

MEANS AND STANDARD DEVIATIONS OF POSTTEST ACHIEVEMENT SCORES OF HIGH ABILITY SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Simulated Section Posttest	26.00	1.41	25.64	2.55	25.86
Laboratory Section Posttest	23.86	1.88	23.57	2.06	23.74
Totals	24.93		24.61		

II. Covariate	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	9.05	3.15	14.57	4.35	11.26

of the achievement test, the analysis of covariance through multiple regression statistical procedure was utilized. The combined means for high ability students on the laboratory section as well as the simulated section of the achievement test, regardless of instructional approaches, were 23.74 and 25.86 respectively, as reported

TABLE XXVI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ACHIEVEMENT SCORES OF HIGH ABILITY SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate R^2_7	.0016			
Approaches (after adjustment) $R^2_7 - R^2_7$	.0034	1	.0034	.24
Test Type (after adjustment) $R^2_{2,7} - R^2_7$	.2253	1	.2253	24.46*
Approaches x Test Type (after adjustment) $R^2_{3,4,5,6,7} - R^2_{1,2,7}$	.0001	1	.0001	.01
Error: Subjects Within Approaches $R^2_{7,8} - R^2_7$	.4766	33	.0144	
Subjects x Test Types Within Approaches $1 - R^2_{3,4,5,6,7,8}$	.2931	32	.0092	

Vector 1 = approach A-approach B; 2 = test type; 3,4,5,6 = test x instruction; 7 = achievement pretest; 8 = equivalent of person vectors

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F-ratio required for significance at the .05 level is 4.15 for 1 and 32 degrees of freedom and 4.14 for 1 and 33 degrees of freedom.

*Significance at the .05 level of significance.

in Table XXV (page 146). There was a significant difference in achievement scores of high ability sixth grade students which favored the simulated section of the achievement test. As reported in Table XXVI (page 147), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_8-6-H) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for high ability students, the analysis of covariance through multiple regression statistical procedure was utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types for high ability sixth grade students, as is shown in Table XXVI (page 147).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_9-6-H) was accepted.

Informational achievement of low ability students. Rejection of the null hypothesis (Ho_4-6) also revealed that the effect of mental ability was in fact different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B, as was indicated in the previous section of this chapter. This finding also necessitated the formulation of not only three alternative hypotheses for high ability students, but also three for their low ability counterparts. Stated in the null form for purposes of statistical treatment, the following alternative hypotheses for low ability sixth grade students were tested:

Ho_{7-6-L}: No significant difference exists between low ability students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units is held constant.

Ho_{8-6-L}: No significant difference exists between the scores low ability students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units is held constant.

Ho_{9-6-L}: No significant interaction exists between the scores low ability students received on instructional approaches and test types, after initial knowledge of the International System of Units is held constant.

In an effort to ascertain whether there were significant differences between the achievement scores of low ability sixth grade students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined achievement means for low ability students exposed to Approaches A and B, regardless of test types, were 18.88 and 20.96 respectively, as reported in Table XXVII. The differences

TABLE XXVII

MEANS AND STANDARD DEVIATIONS OF POSTTEST ACHIEVEMENT SCORES OF LOW ABILITY SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
Simulated Section Posttest	20.85	5.56	21.50	5.37	21.26
Laboratory Section Posttest	16.92	5.25	20.41	5.68	19.11
Totals	18.88		20.96		

II. Covariate	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Mean
Cognitive Pretest	7.23	3.61	9.14	3.47	8.43

between the combined achievement means for low ability sixth grade students were tested and found to be no greater than could be expected by chance as is shown in Table XXVIII.

TABLE XXVIII

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ACHIEVEMENT SCORES OF LOW ABILITY SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate R^2_{7}	.0246			
Approaches (after adjustment) $R^2_{7}-R^2_{7}$	.0182	1	.0182	.79
Test Type (after adjustment) $R^2_{2,7}-R^2_{7}$	.0348	1	.0348	7.57*
Approaches x Test [illegible] adjustment) $R^2_{3,4,5,6,7}-R^2_{1,2,}$[illegible]	.0142	1	.0142	3.09
Error:				
Subjects Within Approaches $R^2_{7,8}-R^2_{7}$	.7600	33	.0230	
Subjects x Test Types Within Approaches $1-R^2_{3,4,5,6,7,8}$	.1481	32	.0046	

Vector 1 = approach A-approach B; 2 = test type; 3,4,5,6 = test x instruction; 7 = achievement pretest; 8 = equivalent of person vectors

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F-ratio required for significance at the .05 level is 4.15 for 1 and 32 degrees of freedom and 4.14 for 1 and 33 degrees of freedom.

*Significance at the .05 level of significance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{7-6-L}) was accepted.

In an effort to ascertain whether there were significant differences between the achievement scores of low ability students on the laboratory section of the achievement test and their scores on the simulated section of the achievement test, the analysis of covariance through multiple regression statistical procedure was utilized. The combined means for low ability students on the laboratory section as well as the simulated section of the achievement test, regardless of instructional approaches, were 19.11 and 21.26 respectively, as reported in Table XXVII (page 150). There was a significant difference in achievement scores of low ability sixth grade students which favored the simulated section of the achievement test. As reported in Table XXVIII (page 151), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{8-6-L}) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for low ability students, the analysis of covariance through multiple regression statistical procedure was utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types for low ability sixth grade students, as is shown in Table XXVIII (page 151).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{9-6-L}) was accepted.

Testing for Homogeneity of Regression Coefficients On Test of Retention Data

The student scores from the researcher-prepared cognitive test of retention (Appendix J) and the achievement tests of retention (Appendix F) were evaluated and the resulting data were analyzed for homogeneity of regression coefficients. This procedure was utilized to ascertain whether the effect of prior knowledge of the International System of Units and mental ability was different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B.

Sixth Grade

Cognitive. The following hypothesis was used to assess the amount of cognitive information which the students had retained:

> Ho_{10-6}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive retention test on mental ability scores, does not significantly improve the prediction of the scores of the cognitive retention test over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in retention, the multiple regression procedure was utilized to compare the regression coefficients of all students in Approaches A and B. Table XXIX is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0027 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive test of retention. The "F" ratio associated with the increment, as shown in Table XXIX, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{10-6}) was accepted.

Achievement--Simulated. The null hypothesis associated with retention on the simulated section of the achievement test was:

> Ho_{11-6}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in retention on the simulated section of the achievement test, the multiple regression procedure was used to compare the

TABLE XXIX

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON RETENTION TEST DATA ON SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Cognitive $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0027	1	.0027	.51
Error Term $1-R^2_{1,7,23,24}$	.4381	82	.0053	
Simulated Section $R^2_{1,7,23,24}-R^2_{1}$	.0353	1	.0353	3.88
Error Term $1-R^2_{1,7,23,24}$	.7481	82	.0091	
Laboratory Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0106	1	.0106	1.14
Error Term $1-R^2_{1,7,23,24}$	.7588	82	.0093	

$R^2_{1,7,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,5,7}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated.

F-ratio required for significance at the .05 level is 3.96 for 1 and 82 degrees of freedom.

*Significance at the .05 level of significance.

regression coefficients of all the students in Approaches A and B. Table XXIX (page 155) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0353 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement test of retention. The "F" ratio associated with the increment, as shown in Table XXIX (page 155), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{11-6}) was accepted.

Achievement--Laboratory. The hypothesis associated with retention on the laboratory section of the achievement test was:

> Ho_{12-6}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in retention on the laboratory section of the achievement test, the multiple regression procedure was again used. Table XXIX (page 155), is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0106 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement test of retention. The "F" ratio associated with this increment is also shown in Table XXIX (page 155), and it was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{12-6}) was accepted.

Testing the Effects of Approaches On Retention Test Data

After an analysis of the homogeneity of regression coefficients on the retention test data, the researcher then tested the effects of the approaches on the data.

Sixth Grade

Cognitive. Due to the acceptance of the null hypothesis (Ho_{10-6}) which revealed that the effect of mental ability and prior knowledge of the International System of Units was in fact the same for students receiving instruction by Approach A and B, the researcher then examined the data for significant differences between approaches using the following hypothesis:

Ho_{13}-6: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant for grade six.

In an effort to ascertain whether there were significant differences between the cognitive retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive retention means for students exposed to Approaches A and B, regardless of test type, were 16.46 and 15.50 respectively, as reported in Table XXX. The differences between the cognitive retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XXXI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{13}-6) was accepted.

Achievement. Due to the acceptance of hypotheses (Ho_{11}-6) and (Ho_{12}-6) which tested for homogeneity of regression coefficients, the researcher was able to ascertain the effects of: (1) Approaches A and B on retention, (2) laboratory and simulated test types on retention, and (3) the interaction of these two factors on retention.

TABLE XXX

MEANS AND STANDARD DEVIATIONS OF COGNITIVE RETENTION
TEST SCORES OF SIXTH GRADE STUDENTS
BY INSTRUCTIONAL APPROACH

I. Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
Cognitive	16.46	4.92	15.50	6.41	15.94

II. Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Mean
Cognitive Pretest	8.39	2.90	10.87	4.46	9.70
Mental Ability	108.41	12.87	101.61	16.06	104.82

Stated in the null form for purposes of statistical treatment, the following retention hypotheses were tested:

> Ho_{14-6}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the test of retention, after initial knowledge of the International System of Units and mental ability are held constant.

TABLE XXXI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF COGNITIVE RETENTION TEST SCORES OF SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.5529			
Cognitive $R^2_{5,7,21}-R^2_{5,7}$	.0063	1	.0063	1.19
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.4408	83	.0053	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.96 for 1 and 83 degrees of freedom.

*Significance at the .05 level of significance.

Ho_{15}-6: No significant difference exists between the scores students received on the laboratory section and the simulated section of the test of retention, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant.

Ho_{16}-6: No significant interaction exists between the retention scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant.

In an effort to ascertain whether there were significant differences between the retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined retention means for students exposed to Approaches A and B, regardless of test types, were 23.55 and 23.1 respectively, as reported in Table XXXII. The differences between the combined retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XXXIII.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{14}-6) was accepted.

In an effort to ascertain whether there were significant differences between the retention scores of students on the laboratory section of the test of retention and their scores on the simulated section of the test of retention, the analysis of covariance through multiple

TABLE XXXII

MEANS AND STANDARD DEVIATIONS OF RETENTION TEST SCORES OF SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
Simulated Section Retention	24.37	3.82	23.70	4.26	24.01
Laboratory Section Retention	22.73	4.31	22.50	4.61	22.61
Totals	23.55		23.10		

II. Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Mean
Cognitive Pretest	8.39	2.90	10.87	4.46	9.70
Mental Ability	108.41	12.87	101.61	16.06	104.82

TABLE XXXIII

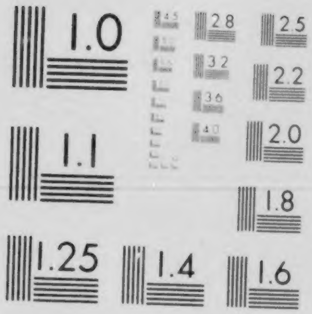
SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF RETENTION TEST SCORES OF SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.2160			
Approaches (after adjustment) $R^2_{5,7,21}-R^2_{5,7}$	.0003	1	.0003	.04
Test Type (after adjustment) $R^2_{5,7,22}-R^2_{5,7}$	.0261	1	.0261	12.55*
Approaches x Test Type (after adjustment) $R^2_{5,7,23}-R^2_{5,7}$	.0002	1	.0002	.01
Error: Subjects Within Approaches $R^2_{5,7,26 \text{ to } 112}-R^2_{5,7,21}$	.5838	85	.0069	
Subjects x Test Types Within Approaches $1-R^2_{5,7,22,23,26 \text{ to } 112}$	.1731	83	.0021	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B: 22 = test type; 23 = approach x test type; 26 to 112 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 83 degrees of freedom and 1 and 85 degrees of freedom.

*Significance at the .05 level of significance.


1.0
4.5
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

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section on the second day. Three weeks after administering the post measures, tests of retention were administered. Each answer sheet was manually inspected, machine scored, processed, and analyzed through the facilities of the Testing and Computer Centers of Central Missouri State University.

Chapter IV

MEASUREMENT AND ANALYSIS OF DATA

Chapter III described the preparation for the experiment, orientation meeting, initial status of groups, instructional procedures followed in conducting the experiment, administration of the instruments, and scoring of the instruments. This chapter presents the results of the data on the mental ability test, attitude scale, pretests, posttests, and tests of retention, by grade level, for the groups involved in the study. A description of the statistical analysis and the findings of the experiment are also reported in this chapter.

Method for Data Analysis

The purpose of this study as described in Chapter I was to ascertain what effect two instructional approaches to teaching the International System of Units would have upon the attitude, cognitive, achievement and retention of fourth, fifth and sixth grade students. The instructional approaches were: (1) Approach A (laboratory activity) provided instruction by having students physically measure three-dimensional objects with metric scales, and (2) Approach B (simulation activity) provided instruction by having students identify measurements from pictures of two-dimensional objects along side of which metric scales had been printed. The effect of the two sections of the achievement test on the initial achievement and retention of the International System of Units was also investigated.

The relative effects of all the data were measured by the scores of scales, pretests, posttests, and tests of retention which were obtained from the eighty-three fourth grade, eighty-two fifth grade and eighty-seven sixth grade students participating in the study. The score of each student is recorded in Appendix A, by grade level.

Since this study was composed of naturally assembled intact classes, it became evident that the initial status of the experimental groups could be different. Therefore, due to the nature of the classes, the researcher analyzed the data resulting from administration of the attitude scale, cognitive test, achievement test and tests of retention by analysis of covariance through multiple regression.

As stated in Chapter I, the assumption of homogeneity of regression coefficients is assumed to be true when adjustments are made for covariates.[1] Therefore, it is important for one to first establish that the regression coefficients in each group are the same before testing in order to ascertain whether or not significant differences exist between the treatment groups.

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[1] Fred Kerlinger and Elazor Pedhazur, Multiple Regression in Behavioral Research (New York: Holt, Rinehart and Winston, Inc., 1973), p. 267.

Due to a definite lack of experimental research data to support SI measurement, the .05 level of confidence has been accepted as the standard confidence level for this study.

Testing for Homogeneity of Regression Coefficients On Posttest Data

The student scores from the researcher-prepared attitude scale (Appendix I), cognitive test (Appendix J), and the simulated and laboratory achievement tests (Appendix F) were evaluated and the resulting data were analyzed for homogeneity of regression coefficients. This procedure was utilized to ascertain whether or not the effect of attitude toward the International System of Units, prior knowledge of the International System of Units and mental ability were different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B. Thus, the null hypotheses which follow were subjected to analysis at each grade level. All hypotheses will be subjected to analysis at a single grade level before moving to another hypothesis, rather than analyzing each individual hypothesis at each grade level. This will allow for a comparison of all hypotheses at a given grade level prior to an analysis of selected hypotheses for combined grades.

Fourth Grade

Attitude. The first hypothesis which was subjected to analysis was:

> Ho_{1-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the attitude scale on the mental ability scores, does not significantly improve the prediction of the scores of the attitude scale over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in attitude, the multiple regression procedure was used to compare the regression coefficients of all the fourth grade students in Approaches A and B. Table II is used to illustrate the separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0007 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the post attitude scale. The "F" ratio associated with this increment, as shown in Table II, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{1-4}) was accepted.

Cognitive. The second hypothesis which was subjected to analysis was:

TABLE II

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON POSTTEST DATA OF FOURTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Attitude $R^2_{1,7,10,23,24} - R^2_{1,5,7,10}$	.0007	1	.0007	.07
Error Term $1 - R^2_{1,7,10,23,24}$	.7214	77	.0094	
Cognitive $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0054	1	.0054	1.42
Error Term $1 - R^2_{1,7,23,24}$	.2984	78	.0038	
Simulated Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0011	1	.0011	.14
Error Term $1 - R^2_{1,7,23,24}$	.6008	78	.0077	
Laboratory Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0001	1	.0001	.01
Error Term $1 - R^2_{1,7,23,24}$	.6495	78	.0083	

$R^2_{1,7,23,24}$ or $R^2_{1,7,10,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,5,7}$ or $R^2_{1,5,7,10}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = Approach A-Approach B; 5 = combined mental ability; 7 = achievement pretest; 10 = attitude pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated

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F-ratio required for significance at the .05 level is 3.96 for both 1 and 78 degrees of freedom and 1 and 77 degrees of freedom.

*Significance at the .05 level.

Ho_{2-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the cognitive achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in the knowledge students had acquired of the International System of Units as measured by the cognitive test, the multiple regression procedure was used to compare the regression coefficients of all fourth grade students in Approaches A and B. Table II (page 86) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0054 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive posttest. The "F" ratio associated with this increment, as shown in Table II (page 86), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{2-4}) was accepted.

Achievement--Simulated. The hypothesis associated with simulated achievement was:

Ho_{3-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in simulated achievement, the multiple regression procedure was again used to compare the regression coefficients of all students in Approaches A and B. Table II (page 86) is also used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0011 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement posttests. The "F" ratio associated with this increment, as shown in Table II (page 86), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{3-4}) was accepted.

Achievement--Laboratory. The hypothesis associated with laboratory achievement was:

Ho_{4-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the achievement test on the mental ability scores, does not

> significantly improve the prediction of the scores of the laboratory section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four.

A test for a significant difference in laboratory achievement using the multiple regression procedure was also used. Table II (page 86) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

The analysis yielded an increment of .0001 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement posttest. The "F" ratio associated with this increment, also shown in Table II (page 86), was found to be no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{4-4}) was accepted.

Testing the Effects of Approaches On Posttest Data

After an analysis of the homogeneity of regression coefficients on the posttest data, the researcher then tested the effects of the approaches on the data.

Fourth Grade

Attitude. Acceptance of the null hypothesis (Ho_{1-4}) revealed that the effect of attitude toward the

International System of Units, knowledge of the International System of Units, and mental ability were in fact the same for all students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significance differences between approaches utilizing the following hypothesis:

> Ho_{5-4}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units, and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the attitude scores of all students who were exposed to Approaches A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The attitude means for students exposed to Approaches A and B were 12.80 and 14.26 respectively, as reported in Table III. The differences between the attitude means for the students were tested and found to be no greater than could be expected by chance, as is shown in Table IV.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{5-4}) was accepted.

TABLE III

MEANS AND STANDARD DEVIATIONS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I.	Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
	Attitude	12.80	6.28	14.26	8.76	13.54
	Cognitive	12.37	4.39	17.10	6.23	14.76

II.	Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Means
	Attitude Pretest	10.17	4.06	10.52	3.76	10.35
	Cognitive Pretest	7.05	2.95	9.43	3.16	8.25
	Mental Ability	104.61	13.84	114.38	15.22	109.55

TABLE IV

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF FOURTH GRADE STUDENT

Source	Proportion of Variance (R^2)	df
Covariate $R^2_{5,7,10}$	.2778	
Attitude (after adjustment) $R^2_{5,7,10,21}-R^2_{5,7,10}$	.0001	1
Error: Subjects x Attitude Within Approaches $1-R^2_{5,7,10,21}$	.7721	78
Covariate (after adjustment) $R^2_{5,7}$	.6901	
Cognitive (after adjustment) $R^2_{5,7,21}-R^2_{5,7}$	.0066	1
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.3033	79

Vector 5 = mental ability; 7 = achievement pretest; 10 = attitude prete
A - approach B

F-ratio required for significance at the .05 level is 3.96 for degrees of freedom, and 1 and 78 degrees of freedom.

*Significance at .05 level of significance.

Cognitive. Acceptance of null hypothesis (Ho_{2-4}) allowed the researcher to examine the data for significant differences between approaches utilizing the following hypothesis:

> Ho_{6-4}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the cognitive scores of students who were exposed to Approach A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive means for students exposed to Approaches A and B were 12.37 and 17.10 respectively, as reported in Table III (page 91). The differences between the cognitive means were tested and found to be no greater than could be expected by chance as is shown in Table IV (page 92).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{6-4}) was accepted.

Achievement. Acceptance of the null hypothesis (Ho_{3-4}) and (Ho_{4-4}) revealed that the effect of mental ability was in fact the same for students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significant differences between approaches and test types utilizing the following hypotheses:

Ho_{7-4}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade four.

Ho_{8-4}: No significant difference exists between the scores students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade four.

Ho_{9-4}: No significant interaction exists between the scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the achievement scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined achievement means for students exposed to Approaches A and B, regardless of test type, were 6.87 and 8.09 respectively, as reported in Table V. The differences between the combined achievement means for students were tested and found to be no greater than could be expected by chance as is shown in Table VI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{7-4}) was accepted.

TABLE V

MEANS AND STANDARD DEVIATIONS OF POSTTEST ACHIEVEMENT SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Test Type	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Simulated Section	7.49	2.20	8.55	1.33	8.02
Laboratory Section	6.24	1.72	7.62	1.75	6.94
Totals	6.87		8.09		
II. Covariates	**Approach A**		**Approach B**		**Grand Means**
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	7.05	2.95	9.43	3.16	8.25
Mental Ability	104.61	13.84	114.38	15.22	109.55

TABLE VI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ACHIEVEMENT SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate				
$R^2_{5,7}$	.3344			
Approaches (after adjustment)				
$R^2_{5,7,21}-R^2_{5,7}$	.0101	1	.0101	2.02
Test Type (after adjustment)				
$R^2_{5,7,22}-R^2_{5,7}$	.0770	1	.0770	35.00*
Approaches x Test Type (after adjustment)				
$R^2_{5,7,23}-R^2_{5,7}$	.0013	1	.0013	.59
Error:				
Subjects Within Approaches				
$R^2_{5,7,26 \text{ to } 108}-R^2_{5,7,21}$	.4029	81	.0050	
Subjects x Test Types Within Approaches				
$1-R^2_{5,7,22,23,26 \text{ to } 108}$	.1740	79	.0022	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B; 22 = test type; 23 = approach x test type; 26 to 108 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 81 degrees of freedom and 1 and 79 degrees of freedom.

*Significance at the .05 level of significance.

In an effort to ascertain whether there were significant differences between the achievement scores of students on the laboratory section of the achievement test and their scores on the simulated section of the achievement test, the analysis of covariance through multiple regression statistical procedure was again utilized. The combined means for students on the laboratory section as well as the simulated section of the achievement test, regardless of instructional approaches, were 8.02 and 6.94 respectively, as reported in Table V (page 95). There was a significant difference in achievement scores of students which favored the simulated section of the achievement test. As reported in Table VI (page 96), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{8-4}) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for students, the analysis of covariance through multiple regression statistical procedure was again utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types for students, as is shown in Table VI (page 96).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{9-4}) was accepted.

Testing for Homogeneity of Regression Coefficients On Test of Retention Data

The student scores from the researcher-prepared cognitive test of retention (Appendix J) and the achievement tests of retention (Appendix F) were evaluated and the resulting data were analyzed for homogeneity of regression coefficients. This procedure was utilized to ascertain whether the effect of prior knowledge of the International System of Units and mental ability were different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B.

Fourth Grade

Cognitive. The following hypothesis was used to assess the amount of cognitive information which the students had retained:

> Ho_{10-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive retention test on mental ability scores, does not significantly improve the prediction of the scores of the cognitive retention test over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in retention, the multiple regression procedure was utilized to compare the regression coefficients of all the students in Approaches A and B. Table VII is used to illustrate the proportion of variance accounted for by using separately

TABLE VII

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON RETENTION TEST DATA OF FOURTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Cognitive $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0071	1	.0071	1.36
Error Term $1-R^2_{1,7,23,24}$	.4065	78	.0052	
Simulated Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0002	1	.0002	.02
Error Term $1-R^2_{1,7,23,24}$	.6734	78	.0086	
Laboratory Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0001	1	.0001	.01
Error Term $1-R^2_{1,7,23,24}$	.6887	78	.0088	

$R^2_{1,7,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,5,7}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated

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F-ratio required for significance at the .05 level is 3.96 for 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0071 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive test of retention. The "F" ratio associated with the increment, as shown in Table VII, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{10-4}) was accepted.

Achievement--Simulated. The null hypothesis associated with retention on the simulated section of the achievement test was:

> Ho_{11-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in retention on the simulated section of the achievement test, the multiple regression procedure was used to compare the regression coefficients of all the students in Approaches A and B. Table VII (page 99), is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0002 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement test of retention. The "F" ratio associated with the increment, as shown in Table VII (page 99) was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{11-4}) was accepted.

Achievement--Laboratory. The hypothesis associated with retention on the laboratory section of the achievement test was:

Ho_{12-4}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade four.

To test for a significant difference in retention on the laboratory section of the achievement test, the multiple regression procedure was again used. Table VII (page 99) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0001 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement test of retention. The "F" ratio associated with this increment, also shown in Table VII (page 99), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{12-4}) was accepted.

Testing the Effects of Approaches On Retention Test Data

After an analysis of the homogeneity of regression coefficients on the retention test data, the researcher then tested the effects of the approaches on the data.

Fourth Grade

Cognitive. Due to the acceptance of the null hypothesis (Ho_{10-4}) which revealed that the effect of mental ability and prior knowledge of the International System of Units was in fact the same for students receiving instruction by Approach A and B, the researcher then examined the data for significant differences between approaches utilizing the following hypothesis:

> Ho_{13-4}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the cognitive retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive retention means for students exposed to Approaches A and B, regardless of test type, were 12.80 and 16.10 respectively, as reported in Table VIII. The differences between the cognitive retention means were tested and found to be no greater than could be expected by chance, as is shown in Table IX.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{13}-4) was accepted.

Achievement. Due to acceptance of hypotheses (Ho_{11}-4) and (Ho_{12}-4) which tested for homogeneity of regression coefficients, the researcher was able to ascertain the effects of: (1) Approaches A and B on retention, (2) simulated and laboratory test types on retention, and (3) the interaction of these two factors on retention.

Stated in the null form for purposes of statistical treatment, the following retention hypotheses were tested:

TABLE VIII

MEANS AND STANDARD DEVIATIONS OF COGNITIVE RETENTION TEST SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
Cognitive	12.80	4.15	16.10	5.09	14.47

II. Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Mean
Cognitive Pretest	7.05	2.95	9.43	3.16	8.25
Mental Ability	104.61	13.84	114.38	15.22	109.55

Ho$_{14-4}$: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the test of retention after initial knowledge of the International System of Units and mental ability are held constant for grade four.

Ho$_{15-4}$: No significant difference exists between the scores students received on the laboratory section and the simulated section of the test of retention, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade four.

TABLE IX

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF COGNITIVE RETENTION TEST SCORES OF FOURTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.5863			
Cognitive $R^2_{5,7,21}-R^2_{5,7}$	.0012	1	.0012	.23
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.4125	79	.0052	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.96 for 1 and 79 degrees of freedom.

*Significance at the .05 level of significance.

Ho16-4: No significant interaction exists between the retention scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade four.

In an effort to ascertain whether there were significant differences between the retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined retention means for students exposed to Approaches A and B, regardless of test type, were 7.17 and 8.01 respectively, as reported in Table X. The differences between the combined retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho14-4) was accepted.

In an effort to ascertain whether there were significant differences between the retention scores of students on the simulated section of the test of retention and their scores on the laboratory section of the test of retention, the analysis of covariance through multiple regression statistical procedure was utilized. The combined means for students on the simulated section as well as the laboratory section of the achievement test,

TABLE X

MEANS AND STANDARD DEVIATIONS OF RETENTION TEST SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Simulated Section Retention	7.51	1.95	8.07	2.24	7.80
Laboratory Section Retention	6.83	1.64	7.95	1.57	7.40
Totals	7.17		8.01		

II. Covariates	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	7.05	2.95	9.43	3.16	8.25
Mental Ability	104.61	13.84	114.38	15.22	109.55

regardless of instructional approaches, were 7.80 and 7.40 respectively, as reported in Table X. There was a significant difference in retention scores of students which favored the simulated section of the retention test.

TABLE XI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF RETENTION TEST SCORES OF FOURTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.3001			
Approaches (after adjustment) $R^2_{5,7,21}-R^2_{5,7}$	.0004	1	.0004	.06
Test Type (after adjustment) $R^2_{5,7,22}-R^2_{5,7}$	.0106	1	.0106	4.61*
Approaches x Test Type (after adjustment) $R^2_{5,7,23}-R^2_{5,7}$	.0051	1	.0051	2.22
Error:				
Subjects Within Approaches $R^2_{5,7,26\text{ to }108}-R^2_{5,7,21}$	.4986	81	.0062	
Subjects x Test Types Within Approaches $1-R^2_{5,7,22,23,26\text{ to }108}$	.1850	79	.0023	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-Approach B; 22 = test type; 23 = approach x test type; 26 to 108 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 81 degrees of freedom and 1 and 79 degrees of freedom.

*Significance at the .05 level.

As reported in Table XI (page 108), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho15-4) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for students, the analysis of covariance through multiple regression statistical procedure was again utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types, as is shown in Table XI (page 108).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho16-4) was accepted.

Upon completion of the analysis of all the data for grade four, the researcher then proceeded to apply the same statistical procedure to the fifth grade data as had been applied to the fourth grade data.

Testing for Homogeneity of Regression Coefficients On Posttest Data

Fifth Grade

Attitude. The first hypothesis which was subjected to analysis was:

Ho_{1-5}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the attitude scale on the mental ability scores, does not significantly improve the prediction of the scores of the attitude scale over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in attitude, the multiple regression procedure was used to compare the regression coefficients of all the fourth grade students in Approaches A and B. Table XII is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0004 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the post attitude scale. The "F" ratio associated with this increment, as shown in Table XII, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{1-5}) was accepted.

Cognitive. The second hypothesis which was subjected to analysis was:

TABLE XII

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON POSTTEST DATA OF FIFTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Attitude $R^2_{1,7,10,23,24}-R^2_{1,5,7,10}$	.0004	1	.0004	.05
Error Term $1-R^2_{1,7,10,23,24}$	.6304	77	.0082	
Cognitive $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0076	1	.0076	1.62
Error Term $1-R^2_{1,7,23,24}$	.3679	78	.0047	
Simulated Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0002	1	.0002	.04
Error Term $1-R^2_{1,7,23,24}$	.4232	78	.0054	
Laboratory Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.004	1	.004	.73
Error Term $1-R^2_{1,7,23,24}$	.4283	78	.0055	

$R^2_{1,7,23,24}$ or $R^2_{1,7,10,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,7,5}$ or $R^2_{1,7,5,10}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 10 = attitude pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 78 degrees of freedom and 1 and 77 degrees of freedom.

*Significance at the .05 level of significance.

Ho2-5: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the cognitive achievement test over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in the knowledge students had acquired of the International System of Units as measured by the cognitive test, the multiple regression procedure was used to compare the regression coefficients of all fifth grade students in Approaches A and B. Table XII (page 111) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0076 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive posttest. The "F" ratio associated with this increment, as shown in Table XII (page 111), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho2-5) was accepted.

Achievement--Simulated. The hypothesis associated with simulated achievement was:

Ho3-5: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in simulated achievement, the multiple regression procedure was again used to compare the regression coefficients of all students in Approaches A and B. Table XII (page 111) is also used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0002 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement posttests. The "F" ratio associated with this increment, as shown in Table XII (page 111), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho3-5) was accepted.

Achievement--Laboratory. The hypothesis associated with laboratory achievement was:

Ho_4-5: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade five.

A test for a significant difference in laboratory achievement using the multiple regression procedure was also used. Table XII (page 111) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

The analysis yielded an increment of .004 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement posttest. The "F" ratio associated with this increment, also shown in Table XII (page 111), was found to be no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_4-5) was accepted.

Testing the Effects of Approaches On Posttest Data

After an analysis of the homogeneity of regression coefficients on the posttest data, the researcher then tested the effects of the approaches on the data.

Fifth Grade

Attitude. Acceptance of the null hypothesis (Ho_1-5) revealed that the effect of attitude toward the International System of Units, knowledge of the International System of Units, and mental ability were in fact the same for all students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significance differences between approaches utilizing the following hypothesis:

> Ho_5-5: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the attitude scores of all students who were exposed to Approaches A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The attitude means for students exposed to Approaches A and B were 16.71 and 15.05 respectively, as reported in Table XIII. The differences between the attitude means for the students were tested and found to be no greater than could be expected by chance, as is shown in Table XIV.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_5-5) was accepted.

TABLE XIII

MEANS AND STANDARD DEVIATIONS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Attitude	16.71	7.36	15.05	8.80	15.88
Cognitive	15.37	5.74	14.24	6.65	14.80

II. Covariates	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Attitude Pretest	12.20	3.45	11.54	3.42	11.87
Cognitive Pretest	9.29	3.60	10.20	4.09	9.74
Mental Ability	112.27	15.17	108.24	15.65	110.26

TABLE XIV

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF FIFTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate				
$R^2_{5,7,10}$	.3658			
Attitude (after adjustment)				
$R^2_{5,7,10,21}-R^2_{5,7,10}$	.0038	1	.0038	.46
Error:				
Subjects x Attitude Within Approaches				
$1-R^2_{5,7,10,21}$	.6304	77	.0082	
Covariate				
$R^2_{5,7}$	.6210			
Cognitive (after adjustment)				
$R^2_{5,7,21}-R^2_{5,7}$	.0035	1	.0035	.73
Error:				
Subjects x Cognitive Within Approaches				
$1-R^2_{5,7,21}$	.3755	78	.0038	

Vector 5 = mental ability; 7 = achievement pretest; 10 = attitude pretest; 21 = approach A-approach B.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 78 degrees of freedom and 1 and 77 degrees of freedom.

*Significance at .05 level of significance.

Cognitive. Acceptance of null hypothesis (Ho_{2-5}) allowed the researcher to examine the data for significant differences between approaches utilizing the following hypothesis:

> Ho_{6-5}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the cognitive scores of students who were exposed to Approach A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive means for students exposed to Approaches A and B were 15.37 and 14.24 respectively, as reported in Table XIII (page 116). The differences between the cognitive means were tested and found to be no greater than could be expected by chance as is shown in Table XIV (page 117).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{6-5}) was accepted.

Achievement. Acceptance of the null hypotheses (Ho_{3-5}) and (Ho_{4-5}) revealed that the effect of mental ability was in fact the same for students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significant differences between approaches and test types utilizing the following hypotheses:

Ho$_{7-5}$: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade five.

Ho$_{8-5}$: No significant difference exists between the scores students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade five.

Ho$_{9-5}$: No significant interaction exists between the scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the achievement scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined achievement means for students exposed to Approaches A and B, regardless of test type, were 21.94 and 20.77 respectively, as reported in Table XV. The differences between the combined achievement means for students were tested and found to be no greater than could be expected by chance as is shown in Table XVI.

TABLE XV

MEANS AND STANDARD DEVIATIONS OF POSTTEST ACHIEVEMENT SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Test Type	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Simulated Section	23.15	4.17	21.95	4.58	22.55
Laboratory Section	20.73	5.26	19.59	5.07	20.16
Totals	21.94		20.77		
II. Covariates	Approach A		Approach B		Grand Means
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	9.29	3.60	10.20	4.09	9.74
Mental Ability	112.27	15.17	108.24	15.65	110.26

TABLE XVI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ACHIEVEMENT SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	f
Covariate				
$R^2_{5,7}$	.5329			
Approaches (after adjustment)				
$R^2_{5,7,21} - R^2_{5,7}$	.0017	1	.0017	.47
Test Type (after adjustment)				
$R^2_{5,7,22} - R^2_{5,7}$	.0578	1	.0578	38.53*
Approaches x Test Type (after adjustment)				
$R^2_{5,7,23} - R^2_{5,7}$	.0000	1	.0000	.00
Error:				
Subjects Within Approaches				
$R^2_{5,7,26 \text{ to } 105} - R^2_{5,7,21}$	.2898	80	.0036	
Subjects x Test Types Within Approaches				
$1 - R^2_{5,7,22,23,26 \text{ to } 105}$	.1177	78	.0015	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B; 22 = test type; 23 = approach x test type; 26 to 105 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 80 degrees of freedom and 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{7-5}) was accepted.

In an effort to ascertain whether there were significant differences between the achievement scores of students on the laboratory section of the achievement test and their scores on the simulated section of the achievement test, the analysis of covariance through multiple regression statistical procedure was again utilized. The combined means for students on the laboratory section as well as the simulated section of the achievement test, regardless of instructional approaches, were 22.55 and 20.16 respectively, as reported in Table XV (page 120). There was a significant difference in achievement scores of students which favored the simulated section of the achievement test. As reported in Table XVI (page 121), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{8-5}) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for students, the analysis of covariance through multiple regression statistical procedure was again utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types for students, as is shown in Table XVI (page 121).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho9-5) was accepted.

Testing for Homogeneity of Regression Coefficients On Test of Retention Data

The student scores from the researcher-prepared cognitive test of retention (Appendix J) and the achievement tests of retention (Appendix F) were evaluated and the resulting data were analyzed for homogeneity of regression coefficients. This procedure was utilized to ascertain whether the effect of prior knowledge of the International System of Units and mental ability were different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B.

Fifth Grade

Cognitive. The following hypothesis was used to assess the amount of cognitive information which the students had retained:

> Ho_{10-5}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive retention test on mental ability scores, does not significantly improve the prediction of the scores of the cognitive retention test over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in retention, the multiple regression procedure was utilized to compare the regression coefficients of all the students in Approaches A and B. Table XVII is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive test of retention. The "F" ratio associated with the increment, as shown in Table XVII, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{10-5}) was accepted.

Achievement--Simulated. The null hypothesis associated with retention on the simulated section of the achievement test was:

> Ho_{11-5}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in retention on the simulated section of the achievement test, the multiple regression procedure was used to compare the regression coefficients of all the students in Approaches

TABLE XVII

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON RETENTION TEST DATA OF FIFTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Cognitive $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0000	1	.0000	.00
Error Term $1 - R^2_{1,7,23,24}$	.4212	78	.0054	
Simulated Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0008	1	.0008	.13
Error Term $1 - R^2_{1,7,23,24}$	.4738	78	.0061	
Laboratory Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0284	1	.0284	3.94
Error Term $1 - R^2_{1,7,23,24}$	.5654	78	.0072	

$R^2_{1,7,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,5,7}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 23 = mental ability-laboratory; 23 = mental ability-simulated.

F-ratio required for significance at the .05 level is 3.96 for 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

TABLE XVIII

MEANS AND STANDARD DEVIATIONS OF COGNITIVE RETENTION TEST SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Cognitive	15.44	4.97	14.59	5.68	15.01

II. Covariates	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	9.29	3.60	10.20	4.09	9.74
Mental Ability	112.27	15.17	108.24	15.65	110.26

A and B. Table XVII (page 125) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0008 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement test of retention. The "F" ratio associated with the increment, as shown in Table XVII (page 125) was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{11-5}) was accepted.

Achievement--Laboratory. The hypothesis associated with retention on the laboratory section of the achievement test was:

> Ho_{12-5}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade five.

To test for a significant difference in retention on the laboratory section of the achievement test, the multiple regression procedure was again used. Table XVII (page 125) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0284 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement test of retention. The "F" ratio associated with this increment, also shown in Table XVII (page 125), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{12-5}) was accepted.

Testing the Effects of Approaches
On Retention Test Data

After an analysis of the homogeneity of regression coefficients on the retention test data, the researcher then tested the effects of the approaches on the data.

Fifth Grade

Cognitive. Due to the acceptance of the null hypothesis (Ho_{10-5}) which revealed that the effect of mental ability and prior knowledge of the International System of Units was in fact the same for students receiving instruction by Approach A and B, the researcher then examined the data for significant differences between approaches utilizing the following hypothesis:

> Ho_{13-5}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the cognitive retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive retention means for students exposed to Approaches A and B, regardless of test type, were 15.44 and 14.59 respectively, as reported in Table XVIII (page 126). The differences between the cognitive retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XIX.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{13}-5) was accepted.

Achievement. Due to acceptance of hypotheses (Ho_{11}-5) and (Ho_{12}-5) which tested for homogeneity of regression coefficients, the researcher was able to ascertain the effects of: (1) Approaches A and B on retention, (2) simulated and laboratory test types on retention, and (3) the interaction of these two factors on retention.

Stated in the null form for purposes of statistical treatment, the following retention hypotheses were tested:

Ho_{14}-5: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the test of retention after initial knowledge of the International System of Units and mental ability are held constant for grade five.

Ho_{15}-5: No significant difference exists between the scores students received on the laboratory section and the simulated section of the test of retention, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade five.

TABLE XIX

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF COGNITIVE RETENTION TEST SCORES OF FIFTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.5741			
Cognitive $R^2_{5,7,21}-R^2_{5,7}$	.0047	1	.0047	.87
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.4212	78	.0054	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.96 for 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

Ho_{16}-5: No significant interaction exists between the retention scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade five.

In an effort to ascertain whether there were significant differences between the retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined retention means for students exposed to Approaches A and B, regardless of test type, were 23.45 and 21.58 respectively, as reported in Table XX. The differences between the combined retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XXI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{14}-5) was accepted.

In an effort to ascertain whether there were significant differences between the retention scores of students on the simulated section of the test of retention and their scores on the laboratory section of the test of retention, the analysis of covariance through multiple regression statistical procedure was utilized. The combined means for students on the simulated section as well as the laboratory section of the achievement test, regardless of instructional approaches, were 23.21 and 21.82 respectively, as reported in Table XX. There was a

TABLE XX

MEANS AND STANDARD DEVIATIONS OF RETENTION TEST SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
Simulated Section Retention	24.15	4.15	22.27	4.54	23.21
Laboratory Section Retention	22.76	3.50	20.88	4.59	21.82
Totals	23.45		21.58		

II. Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Mean
Covariate Pretest	9.29	3.60	10.20	4.09	9.74
Mental Ability	112.27	15.17	108.24	15.65	110.26

TABLE XXI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF RETENTION TEST SCORES OF FIFTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate				
$R^2_{5,7}$	.4332			
Approaches (after adjustment)				
$R^2_{5,7,21} - R^2_{5,7}$	.0194	1	.0194	4.41*
Test Type (after adjustment)				
$R^2_{5,7,22} - R^2_{5,7}$	.0253	1	.0253	12.05*
Approaches x Test Type (after adjustment)				
$R^2_{5,7,23} - R^2_{5,7}$	.0000	1	.0000	.00
Error:				
Subjects Within Approaches				
$R^2_{5,7,26 \text{ to } 105} - R^2_{5,7,21}$	.3547	80	.0044	
Subjects x Test Types Within Approaches				
$1 - R^2_{5,7,22,23,26 \text{ to } 105}$	.1638	78	.0021	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B; 22 = test type; 23 = approach x test type; 26 to 105 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 80 degrees of freedom and 1 and 78 degrees of freedom.

*Significance at the .05 level of significance.

significant difference in retention scores of students which favored the simulated section of the retention test. As reported in Table XXI (page 133), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{15-5}) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for students, the analysis of covariance through multiple regression statistical procedure was again utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types, as is shown in Table XXI (page 133).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{16-5}) was accepted.

Upon completion of the analysis of all the data for grade five, the researcher then proceeded to apply the same statistical procedures to the sixth grade data as had been applied to the fourth and fifth grade data.

Test for Homogeneity of Regression Coefficients On Posttest Data

Sixth Grade

Attitude. The first hypothesis which was subjected to analysis was:

Ho_{1-6}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the attitude scale on the mental ability scores, does not significantly improve the prediction of the scores of the attitude scale over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in attitude, the multiple regression procedure was used to compare two regression coefficients of all the sixth grade students in Approaches A and B. Table XXII is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0265 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the post attitude scale. The "F" ratio associated with this increment, as shown in Table XXII, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{1-6}) was accepted.

Cognitive. The second hypothesis which was subjected to analysis was:

TABLE XXII

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON POSTTEST DATA OF SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Attitude $R^2_{1,7,10,23,24} - R^2_{1,5,7,10}$	.0265	1	.0265	3.92
Error Term $1 - R^2_{1,7,10,23,24}$	.5475	81	.0068	
Cognitive $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0199	1	.0199	3.49
Error Term $1 - R^2_{1,7,23,24}$	.4695	82	.0057	
Simulated Section $R^2_{1,7,23,24} - R^2_{1,5,7}$	.0022	1	.0022	.26
Error Term $1 - R^2_{1,7,23,24}$	.7032	82	.0086	
Laboratory Section $R^2_{1,7,23,24} - R^2_{1,7,5}$	.0492	1	.0492	5.79*
Error Term $1 - R^2_{1,7,23,24}$	.6985	82	.0085	

$R^2_{1,7,23,24}$ or $R^2_{1,7,10,23,24}$ = proportion of variance accounted for by using regression coefficients for each group

$R^2_{1,5,7}$ or $R^2_{1,5,7,10}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 10 = attitude pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 82 degrees of freedom and 1 and 81 degrees of freedom.

*Significance at the .05 level of significance.

Ho_2-6: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the cognitive achievement test over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in the knowledge students had acquired of the International System of Units as measured by the cognitive test, the multiple regression procedure was used to compare the regression coefficients of all sixth grade students in Approaches A and B. Table XXII (page 136) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0199 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive posttest. The "F" ratio associated with this increment, as shown in Table XXII (page 136), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_2-6) was accepted.

Achievement--Simulated. The hypothesis associated with simulated achievement was:

Ho_3-6: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in simulated achievement the multiple regression procedure was again used to compare the regression coefficients for all students in Approaches A and B. Table XXII (page 136) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0022 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement posttests. The "F" ratio associated with this increment, as shown in Table XXII (page 136), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_3-5) was accepted.

Achievement--Laboratory. The hypothesis associated with laboratory achievement was:

Ho_4-6: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade six.

A test for a significant difference in laboratory achievement using the multiple regression procedure was also used. Table XXII (page 136) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

The analysis yielded an increment of .0492 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement posttests. The "F" ratio associated with this increment, also shown in Table XXII (page 136), was found to be greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_4-6) was rejected.

Testing the Effects of Approaches On Posttest Data

Sixth Grade

Attitude. Acceptance of the null hypothesis (Ho_1-6) revealed that the effect of attitude toward the International System of Units, knowledge of the International

System of Units, and mental ability were in fact the same for all students receiving instruction by Approach A and B. This allowed the researcher to examine the data for significant differences between approaches utilizing the following hypothesis:

> Ho_{5-6}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units and mental ability are held constant for grade six.

In an effort to ascertain whether there were significant differences between the attitude scores of students who were exposed to Approaches A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The attitude means for students exposed to Approach A and B were 19.37 and 12.76 respectively, as reported in Table XXIII. The differences between the attitude means were tested and found to be much greater than could be expected by chance as is shown in Table XXIV. The significance was in favor of Approach A, the laboratory approach.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{5-6}) was rejected.

Cognitive. Acceptance of null hypothesis (Ho_{2-6}) allowed the researcher to examine the data for significant

TABLE XXIII

MEANS AND STANDARD DEVIATIONS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
Attitude	19.37	8.09	12.76	9.01	15.88
Cognitive	17.41	5.11	16.35	6.19	16.85

II. Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Mean
Attitude Pretest	10.15	3.17	11.43	3.56	10.83
Cognitive Pretest	8.39	2.90	10.87	4.46	9.70
Mental Ability	108.41	12.87	101.61	16.06	104.81

TABLE XXIV

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ATTITUDE AND COGNITIVE SCORES OF SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7,10}$	.2327			
Attitude (after adjustment) $R^2_{5,7,10,21}-R^2_{5,7,10}$	.1914	1	.1914	27.34*
Error: Subjects x Attitude Within Approaches $1-R^2_{5,7,10,21}$	.5759	82	.0070	
Covariate (after adjustment) $R^2_{5,7}$	.4969			
Cognitive (after adjustment) $R^2_{5,7,21}-R^2_{5,7}$	.0137	1	.0137	2.32
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.4894	83	.0059	

Vector 5 = mental ability; 7 = achievement pretest; 10 = attitude pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.96 for both 1 and 83 degrees of freedom and 1 and 82 degrees of freedom.

*Significance at the .05 level of significance.

differences between approaches utilizing the following hypothesis:

> Ho_{6}-6: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade six.

In an effort to ascertain whether there were significant differences between the cognitive scores of students who were exposed to Approach A and B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive means for students exposed to Approaches A and B were 17.41 and 16.35 respectively, as reported in Table XXIII (page 141). The difference between the cognitive means were tested and found to be no greater than could be expected by chance as is shown in Table XXIV (page 142).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{6}-6) was accepted.

Achievement. Rejection of the null hypothesis (Ho_{4}-6) revealed that the effect of knowledge of the International System of Units and mental ability were different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B. This necessitated the formulation of alternative hypotheses, three for high ability students and three for low ability students, which then took the place of the original hypotheses (Ho_{7-6})-(Ho_{9-6}), which could no longer be used due to the findings in hypothesis (Ho_{4-6}). These new hypotheses were designed to ascertain the effect of: (1) Approaches A and B on achievement, (2) laboratory and simulated test types on achievement, and (3) the interaction of these two factors on achievement.

The high ability group consisted of students in the upper 40 percent of a distribution of mental ability scores of all sixth grade students participating in the study, and the low ability group consisted of students having scores in the lower 40 percent of all sixth grade student mental ability scores. As a result of this process, all of the sixth grade students who scored 112 or above on the Henmon-Nelson Test of Mental Ability (Form 1) were placed in the high ability group, while students who scored 102 or below on the same instrument were placed in the low ability group. The mental ability scores are located in Appendix A.

Informational achievement of high ability students. Stated in the null form for purposes of statistical treatment, the following alternative hypotheses for high ability sixth grade students were tested:

Ho_{7-6-H}: No significant difference exists between high ability students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units is held constant.

Ho_8-6-H: No significant difference exists between the scores high ability students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units is held constant.

Ho_9-6-H: No significant interaction exists between the scores high ability students received on instructional approaches and test types, after initial knowledge of the International System of Units is held constant.

In an effort to ascertain whether there were significant differences between the achievement scores of high ability sixth grade students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined achievement means for high ability students exposed to Approaches A and B, regardless of test types, were 24.93 and 24.61 respectively, as reported in Table XXV. The differences between the combined achievement means for high ability sixth grade students were tested and found to be no greater than could be expected by chance as is shown in Table XXVI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_7-6-H) was accepted.

In an effort to ascertain whether there were significant differences between the achievement scores of high ability students on the laboratory section of the achievement tests and their scores on the simulated section

TABLE XXV

MEANS AND STANDARD DEVIATIONS OF POSTTEST ACHIEVEMENT SCORES OF HIGH ABILITY SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Simulated Section Posttest	26.00	1.41	25.64	2.55	25.86
Laboratory Section Posttest	23.86	1.88	23.57	2.06	23.74
Totals	24.93		24.61		

II. Covariate	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	9.05	3.15	14.57	4.35	11.26

of the achievement test, the analysis of covariance through multiple regression statistical procedure was utilized. The combined means for high ability students on the laboratory section as well as the simulated section of the achievement test, regardless of instructional approaches, were 23.74 and 25.86 respectively, as reported

TABLE XXVI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ACHIEVEMENT SCORES OF HIGH ABILITY SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate R^2_{7}	.0016			
Approaches (after adjustment) $R^2_{7}-R^2_{7}$	.0034	1	.0034	.24
Test Type (after adjustment) $R^2_{2,7}-R^2_{7}$	.2253	1	.2253	24.46*
Approaches x Test Type (after adjustment) $R^2_{3,4,5,6,7}-R^2_{1,2,7}$	.0001	1	.0001	.01
Error: Subjects Within Approaches $R^2_{7,8}-R^2_{7}$	.4766	33	.0144	
Subjects x Test Types Within Approaches $1-R^2_{3,4,5,6,7,8}$	.2931	32	.0092	

Vector 1 = approach A-approach B; 2 = test type; 3,4,5,6 = test x instruction; 7 = achievement pretest; 8 = equivalent of person vectors

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F-ratio required for significance at the .05 level is 4.15 for 1 and 32 degrees of freedom and 4.14 for 1 and 33 degrees of freedom.

*Significance at the .05 level of significance.

in Table XXV (page 146). There was a significant difference in achievement scores of high ability sixth grade students which favored the simulated section of the achievement test. As reported in Table XXVI (page 147), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_8-6-H) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for high ability students, the analysis of covariance through multiple regression statistical procedure was utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types for high ability sixth grade students, as is shown in Table XXVI (page 147).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_9-6-H) was accepted.

Informational achievement of low ability students. Rejection of the null hypothesis (Ho_4-6) also revealed that the effect of mental ability was in fact different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B, as was indicated in the previous section of this chapter. This finding also necessitated the formulation of not only three alternative hypotheses for high ability students, but also three for their low ability counterparts. Stated in the null form for purposes of statistical treatment, the following alternative hypotheses for low ability sixth grade students were tested:

Ho_{7-6-L}: No significant difference exists between low ability students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units is held constant.

Ho_{8-6-L}: No significant difference exists between the scores low ability students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units is held constant.

Ho_{9-6-L}: No significant interaction exists between the scores low ability students received on instructional approaches and test types, after initial knowledge of the International System of Units is held constant.

In an effort to ascertain whether there were significant differences between the achievement scores of low ability sixth grade students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined achievement means for low ability students exposed to Approaches A and B, regardless of test types, were 18.88 and 20.96 respectively, as reported in Table XXVII. The differences

TABLE XXVII

MEANS AND STANDARD DEVIATIONS OF POSTTEST ACHIEVEMENT SCORES OF LOW ABILITY SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Simulated Section Posttest	20.85	5.56	21.50	5.37	21.26
Laboratory Section Posttest	16.92	5.25	20.41	5.68	19.11
Totals	18.88		20.96		

II. Covariate	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	7.23	3.61	9.14	3.47	8.43

between the combined achievement means for low ability sixth grade students were tested and found to be no greater than could be expected by chance as is shown in Table XXVIII.

TABLE XXVIII

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF POSTTEST ACHIEVEMENT SCORES OF LOW ABILITY SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate R^2_{7}	.0246			
Approaches (after adjustment) $R^2_{7}-R^2_{7}$	.0182	1	.0182	.79
Test Type (after adjustment) $R^2_{2,7}-R^2_{7}$	.0348	1	.0348	7.57*
Approaches x Test T[illegible]r adjustment) $R^2_{3,4,5,6,7}-R^2_{1,2,}$[illegible]	.0142	1	.0142	3.09
Error: Subjects Within Approaches $R^2_{7,8}-R^2_{7}$	.7600	33	.0230	
Subjects x Test Types Within Approaches $1-R^2_{3,4,5,6,7,8}$	.1481	32	.0046	

Vector 1 = approach A-approach B; 2 = test type; 3,4,5,6 = test x instruction; 7 = achievement pretest; 8 = equivalent of person vectors

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F-ratio required for significance at the .05 level is 4.15 for 1 and 32 degrees of freedom and 4.14 for 1 and 33 degrees of freedom.

*Significance at the .05 level of significance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{7-6-L}) was accepted.

In an effort to ascertain whether there were significant differences between the achievement scores of low ability students on the laboratory section of the achievement test and their scores on the simulated section of the achievement test, the analysis of covariance through multiple regression statistical procedure was utilized. The combined means for low ability students on the laboratory section as well as the simulated section of the achievement test, regardless of instructional approaches, were 19.11 and 21.26 respectively, as reported in Table XXVII (page 150). There was a significant difference in achievement scores of low ability sixth grade students which favored the simulated section of the achievement test. As reported in Table XXVIII (page 151), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{8-6-L}) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for low ability students, the analysis of covariance through multiple regression statistical procedure was utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types for low ability sixth grade students, as is shown in Table XXVIII (page 151).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{9-6-L}) was accepted.

Testing for Homogeneity of Regression Coefficients On Test of Retention Data

The student scores from the researcher-prepared cognitive test of retention (Appendix J) and the achievement tests of retention (Appendix F) were evaluated and the resulting data were analyzed for homogeneity of regression coefficients. This procedure was utilized to ascertain whether the effect of prior knowledge of the International System of Units and mental ability was different for students receiving instruction by Approach A than it was for students receiving instruction by Approach B.

Sixth Grade

Cognitive. The following hypothesis was used to assess the amount of cognitive information which the students had retained:

> Ho_{10-6}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive retention test on mental ability scores, does not significantly improve the prediction of the scores of the cognitive retention test over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in retention, the multiple regression procedure was utilized to compare the regression coefficients of all students in Approaches A and B. Table XXIX is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0027 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the cognitive test of retention. The "F" ratio associated with the increment, as shown in Table XXIX, was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{10-6}) was accepted.

Achievement--Simulated. The null hypothesis associated with retention on the simulated section of the achievement test was:

> Ho_{11-6}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in retention on the simulated section of the achievement test, the multiple regression procedure was used to compare the

TABLE XXIX

REGRESSION ANALYSIS OF THE EFFECT OF MENTAL ABILITY ON RETENTION TEST DATA ON SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Cognitive $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0027	1	.0027	.51
Error Term $1-R^2_{1,7,23,24}$	.4381	82	.0053	
Simulated Section $R^2_{1,7,23,24}-R^2_{1}$	.0353	1	.0353	3.88
Error Term $1-R^2_{1,7,23,24}$	.7481	82	.0091	
Laboratory Section $R^2_{1,7,23,24}-R^2_{1,5,7}$	.0106	1	.0106	1.14
Error Term $1-R^2_{1,7,23,24}$	.7588	82	.0093	

$R^2_{1,7,23,24}$ = proportion of variance accounted for by using separate regression coefficients for each group

$R^2_{1,5,7}$ = proportion of variance accounted for by using a common regression coefficient for both groups

Vector 1 = approach A-approach B; 5 = combined mental ability; 7 = achievement pretest; 23 = mental ability-laboratory; 24 = mental ability-simulated.

F-ratio required for significance at the .05 level is 3.96 for 1 and 82 degrees of freedom.

*Significance at the .05 level of significance.

regression coefficients of all the students in Approaches A and B. Table XXIX (page 155) is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0353 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the simulated section of the achievement test of retention. The "F" ratio associated with the increment, as shown in Table XXIX (page 155), was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{11-6}) was accepted.

Achievement--Laboratory. The hypothesis associated with retention on the laboratory section of the achievement test was:

> Ho_{12-6}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade six.

To test for a significant difference in retention on the laboratory section of the achievement test, the multiple regression procedure was again used. Table XXIX (page 155), is used to illustrate the proportion of variance accounted for by using separately derived regression coefficients for each approach as compared to a common regression coefficient for both approaches.

This analysis yielded an increment of .0106 when separate regression coefficients for each approach were compared to a common regression coefficient for both approaches on the laboratory section of the achievement test of retention. The "F" ratio associated with this increment is also shown in Table XXIX (page 155), and it was no greater than could be expected by chance. On the basis of these results, the null hypothesis (Ho_{12-6}) was accepted.

Testing the Effects of Approaches On Retention Test Data

After an analysis of the homogeneity of regression coefficients on the retention test data, the researcher then tested the effects of the approaches on the data.

Sixth Grade

Cognitive. Due to the acceptance of the null hypothesis (Ho_{10-6}) which revealed that the effect of mental ability and prior knowledge of the International System of Units was in fact the same for students receiving instruction by Approach A and B, the researcher then examined the data for significant differences between approaches using the following hypothesis:

Ho_{13}-6: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant for grade six.

In an effort to ascertain whether there were significant differences between the cognitive retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive retention means for students exposed to Approaches A and B, regardless of test type, were 16.46 and 15.50 respectively, as reported in Table XXX. The differences between the cognitive retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XXXI.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{13}-6) was accepted.

Achievement. Due to the acceptance of hypotheses (Ho_{11}-6) and (Ho_{12}-6) which tested for homogeneity of regression coefficients, the researcher was able to ascertain the effects of: (1) Approaches A and B on retention, (2) laboratory and simulated test types on retention, and (3) the interaction of these two factors on retention.

TABLE XXX

MEANS AND STANDARD DEVIATIONS OF COGNITIVE RETENTION TEST SCORES OF SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
Cognitive	16.46	4.92	15.50	6.41	15.94

II. Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Mean
Cognitive Pretest	8.39	2.90	10.87	4.46	9.70
Mental Ability	108.41	12.87	101.61	16.06	104.82

Stated in the null form for purposes of statistical treatment, the following retention hypotheses were tested:

Ho_{14-6}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the test of retention, after initial knowledge of the International System of Units and mental ability are held constant.

TABLE XXXI

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF COGNITIVE RETENTION TEST SCORES OF SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.5529			
Cognitive $R^2_{5,7,21}-R^2_{5,7}$	.0063	1	.0063	1.19
Error: Subjects x Cognitive Within Approaches $1-R^2_{5,7,21}$	.4408	83	.0053	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.96 for 1 and 83 degrees of freedom.

*Significance at the .05 level of significance.

Ho_{15}-6: No significant difference exists between the scores students received on the laboratory section and the simulated section of the test of retention, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant.

Ho_{16}-6: No significant interaction exists between the retention scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant.

In an effort to ascertain whether there were significant differences between the retention scores of students receiving instruction by Approach A and those receiving instruction by Approach B, the analysis of covariance through multiple regression statistical procedure was utilized. The combined retention means for students exposed to Approaches A and B, regardless of test types, were 23.55 and 23.1 respectively, as reported in Table XXXII. The differences between the combined retention means were tested and found to be no greater than could be expected by chance, as is shown in Table XXXIII.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{14}-6) was accepted.

In an effort to ascertain whether there were significant differences between the retention scores of students on the laboratory section of the test of retention and their scores on the simulated section of the test of retention, the analysis of covariance through multiple

TABLE XXXII

MEANS AND STANDARD DEVIATIONS OF RETENTION TEST SCORES OF SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

I.	Source	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Mean Totals
	Simulated Section Retention	24.37	3.82	23.70	4.26	24.01
	Laboratory Section Retention	22.73	4.31	22.50	4.61	22.61
	Totals	23.55		23.10		

II.	Covariates	Approach A Mean	Approach A S.D.	Approach B Mean	Approach B S.D.	Grand Mean
	Cognitive Pretest	8.39	2.90	10.87	4.46	9.70
	Mental Ability	108.41	12.87	101.61	16.06	104.82

TABLE XXXIII

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF RETENTION TEST SCORES OF SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH AND TEST TYPE

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7}$	.2160			
Approaches (after adjustment) $R^2_{5,7,21}-R^2_{5,7}$	.0003	1	.0003	.04
Test Type (after adjustment) $R^2_{5,7,22}-R^2_{5,7}$	.0261	1	.0261	12.55*
Approaches x Test Type (after adjustment) $R^2_{5,7,23}-R^2_{5,7}$	.0002	1	.0002	.01
Error:				
Subjects Within Approaches $R^2_{5,7,26 \text{ to } 112}-R^2_{5,7,21}$	.5838	85	.0069	
Subjects x Test Types Within Approaches $1-R^2_{5,7,22,23,26 \text{ to } 112}$	.1731	83	.0021	

Vector 5 = mental ability; 7 = achievement pretest; 21 = approach A-approach B; 22 = test type; 23 = approach x test type; 26 to 112 = person vectors.

F-ratio required for significance at the .05 level is 3.96 for both 1 and 83 degrees of freedom and 1 and 85 degrees of freedom.

*Significance at the .05 level of significance.

1.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0
10
11
12
14
16
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

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regression statistical procedure was utilized. The combined means for students on the laboratory section as well as the simulated section of the achievement test, regardless of instructional approaches, were 22.61 and 24.01 respectively, as reported in Table XXXII (page 162). There was a significant difference in retention scores of students which favored the simulated section of the retention test. As reported in Table XXXIII (page 163), the difference was greater than could be expected by chance.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{15-6}) was rejected.

In an effort to ascertain whether a significant interaction existed between instructional approaches and test types for students, the analysis of covariance through multiple regression statistical procedure was utilized. This analysis revealed no significant difference in the interaction between instructional approaches and test types, as is shown in Table XXXIII (page 163).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{16-6}) was accepted.

Testing the Effects of Approaches On Combined Posttest Data

Combined Grades

Attitude. Since there were no significant differences identified when testing for the homogeneity of regression coefficients on attitude posttest data for hypotheses (Ho_{1-4}), (Ho_{1-5}) or (Ho_{1-6}), the researcher was able to omit this procedure and test for the effects of approaches on combined attitude posttest data. The hypothesis utilized to make this assessment was:

> Ho_{17}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of all fourth, fifth and sixth grade students on the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units and mental ability are held constant.

In an effort to ascertain whether there were significant differences between the attitude scores of all students who were exposed to Approaches A and B, regardless of grade level, the analysis of covariance through multiple regression statistical procedure was utilized. The attitude means for students exposed to Approaches A and B were 16.29 and 13.98 respectively, as reported in Table XXXIV. The differences between the attitude means for the students were tested and found to be much greater than could be expected by chance, as is shown in Table XXXV. The significant difference favored

TABLE XXXIV

MEANS AND STANDARD DEVIATIONS OF COMBINED POSTTEST ATTITUDE AND COGNITIVE SCORES OF FOURTH, FIFTH AND SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Attitude	16.29	7.76	13.98	8.95	15.11
Cognitive	15.05	5.52	15.92	6.46	15.50

II. Covariates	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Attitude Pretest	10.84	3.71	11.17	3.61	11.01
Cognitive Pretest	8.24	3.30	10.19	4.00	9.24
Mental Ability	108.43	14.33	107.88	16.52	108.15

TABLE XXXV

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF COMBINED POSTTEST ATTITUDE AND COGNITIVE SCORES OF FOURTH, FIFTH AND SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate				
$R^2_{5,7,10}$	.2803			
Attitude (after adjustment)				
$R^2_{5,7,10,21}-R^2_{5,7,10}$	.0332	1	.0332	11.86*
Error:				
Subjects x Attitude Within Approaches				
$1-R^2_{5,7,10,21}$	.6865	247	.0028	
Covariate				
$R^2_{5,7}$	.5586			
Cognitive (after adjustment)				
$R^2_{5,7,21}-R^2_{5,7}$	.0010	1	.0010	.56
Error:				
Subjects x Cognitive Within Approaches				
$1-R^2_{5,7,21}$	.4404	248	.0018	

Vector 5 = mental ability; 7 = achievement pretest; 10 = attitude pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.88 for both 1 and 248 degrees of freedom and 1 and 247 degrees of freedom.

*Significance at the .05 level of significance.

those students who studied the International System of Units by Approach A, the laboratory approach.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{17}) was rejected.

Cognitive. No significant differences were identified when testing for the homogeneity of regression coefficients on the cognitive posttest data for hypotheses (Ho_{2-4}), (Ho_{2-5}) or (Ho_{2-6}) which enabled the researcher to immediately test for the effects of approaches on combined cognitive posttest data. The hypothesis utilized to make this assessment was:

> Ho_{18}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of all fourth, fifth and sixth grade students on the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant.

In an effort to ascertain whether there were significant differences between the cognitive posttest scores of all students who were exposed to Approaches A and B, regardless of grade level, the analysis of covariance through multiple regression statistical procedure was utilized. The cognitive means for students exposed to Approaches A and B were 15.05 and 15.92 respectively, as reported in Table XXXIV (page 166). The differences between the cognitive means for the students were tested and found to be no greater than could be expected by chance, as is shown in Table XXXV (page 167).

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{18}) was accepted.

Testing the Effects of Approaches On Combined Retention Test Data

Combined Grades

Cognitive. Since there were no significant differences identified when testing for the homogeneity of regression coefficients on the cognitive test of retention data for hypotheses (Ho_{13-4}), (Ho_{13-5}) or (Ho_{13-6}), the researcher was able to omit this procedure and test for the effects of approaches on the combined cognitive test of retention data. The hypothesis utilized to make this assessment was:

> Ho_{19}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of all fourth, fifth and sixth grade students on the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant.

In an effort to ascertain whether there were significant differences between the cognitive test of retention scores of all students who were exposed to Approaches A and B, regardless of grade level, the analysis of covariance through multiple regression statistical procedure was utilized the cognitive means for students exposed to Approaches A and B were 14.90 and 15.40 respectively, as reported in Table XXXVI. The differences between the cognitive means for the students were tested and found to be no greater than could be expected by chance, as is shown in Table XXXVII.

On the basis of the results of the analysis of covariance through multiple regression, the null hypothesis (Ho_{19}) was accepted.

The researcher had originally planned to test the effects of approaches and test types on combined posttest and test of retention data. This was not possible due to the fact that the computer on the campus of Central Missouri State University did not have sufficient memory to generate the two hundred and fifty-two person vectors needed.

Testing the Effects of Approaches On Teacher Posttest Data

Teachers

Attitude. The hypothesis which was used to assess the differences in pretest and posttest attitude scores between the teachers who presented the two approaches was:

> Ho_{20}: No significant difference exists between teachers who taught the International System of Units by Approach A and those who taught by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units was held constant.

TABLE XXXVI

MEANS AND STANDARD DEVIATIONS OF COMBINED COGNITIVE RETENTION TEST SCORES OF FOURTH, FIFTH AND SIXTH GRADE STUDENTS BY INSTRUCTIONAL APPROACH

I. Source	Approach A		Approach B		Mean Totals
	Mean	S.D.	Mean	S.D.	
Cognitive	14.90	4.94	15.40	5.81	15.16

II. Covariates	Approach A		Approach B		Grand Mean
	Mean	S.D.	Mean	S.D.	
Cognitive Pretest	8.24	3.30	10.19	4.00	9.24
Mental Ability	108.43	14.33	107.88	16.52	108.15

In an effort to ascertain whether there were significant differences between the attitude of the teachers who were exposed to Approaches A and B, a t-test for correlated observations was used. The t-test revealed a significant difference between the pretest and posttest scores for both groups of teachers with regard to gain in teacher attitude toward the International System of Units,

TABLE XXXVII

SUMMARY OF MULTIPLE REGRESSION ANALYSIS OF COMBINED COGNITIVE RETENTION TEST SCORES OF FOURTH, FIFTH AND SIXTH GRADE STUDENTS

Source	Proportion of Variance (R^2)	df	ms	F
Covariate $R^2_{5,7,10}$	.5438			
Attitude (after adjustment) $R^2_{5,7,10,21}-R^2_{5,7,10}$	.0034	1	.0034	1.89
Error: Subjects x Attitude Within Approaches $1-R^2_{5,7,10,21}$	.4528	248	.0018	

Vector 5 = mental ability; 7 = achievement pretest; 10 = attitude pretest; 21 = approach A-approach B

F-ratio required for significance at the .05 level is 3.88 for 1 and 248 degrees of freedom.

*Significance at .05 level of significance.

as measured by the attitude scale which had been developed by the researcher. This was the same instrument which had been used by the fourth, fifth and sixth grade students. An example of this instrument is provided in Appendix I. Table XXXVIII provides the results of the t-test for gains in teacher attitude for Approach A while Table XXXIX provides the results for Approach B.

The pretest mean for the six teachers in Approach A was 15.33, while the posttest mean for this group was 24.83, yielding a combined mean gain of 9.5, as is shown in Table XXXVIII. The difference between the pretest and posttest means revealed a t-value of 13.19, which was found to be greater than could be expected by chance.

The pretest mean for the six teachers in Approach B was 14.5, while the posttest mean for this group was 26.17, yielding a combined mean gain of 11.67, as is shown in Table XXXIX. The difference between the pretest and posttest means revealed a t-value of 7.20, which was found to be greater than could be expected by chance.

Although there was no statistical analysis applied to the combined mean gains for Approaches A and B, it is worthy to note the levels of significance for the t-values of Approach A and B which were 13.19 and 7.20, respectively. This indicates a significant difference in teacher attitude favoring Approach A, the laboratory approach.

TABLE XXXVIII

t-TEST FOR CORRELATED OBSERVATIONS OF APPROACH A TEACHERS ATTITUDE TOWARD SI MEASUREMENT

Teacher/ Grade	Pretest Score	Posttest Score	Sum of Differences	Square of Differences
A--4	18	29	11	121
B--4	14	23	9	81
C--5	16	23	7	49
D--5	15	27	12	144
E--6	19	28	9	81
F--6	10	19	9	81
N=6	$\bar{X}_1=15.33$	$\bar{X}_2=24.83$	$\Sigma D=57$	$\Sigma D^2=557$

t=13.19**

Critical values of t for significance at the .05 level are 2.57 for 1 and 5 degrees of freedom. Critical values of t for significance at the .01 level are 4.03 for 1 and 5 degrees of freedom.

*Significance at the .05 level.

**Significance at the .01 level.

On the basis of the results of the two t-tests for correlated observations, the null hypothesis (Ho_{20}) was rejected.

TABLE XXXIX

t-TEST FOR CORRELATED OBSERVATIONS OF APPROACH B TEACHERS ATTITUDE TOWARD SI MEASUREMENT

Teacher/ Grade	Pretest Scores	Posttest Scores	Sum of Differences	Square of Differences
A--4	14	28	14	196
B--4	13	29	16	256
C--5	18	23	5	25
D--5	13	22	9	81
E--6	13	25	12	144
F--6	16	29	13	169
N=6	$\bar{X}_1=14.5$	$\bar{X}_2=26.17$	$\Sigma D=69$	$\Sigma D^2=872$

t=7.20**

Critical values of t for significance at the .05 level are 2.57 for 1 and 5 degrees of freedom. Critical values of t for significance at the .01 level are 4.03 for 1 and 5 degrees of freedom.

*Significance at the .05 level.

**Significance at the .01 level.

Summary

The purpose of this study was to compare the effects of two instructional approaches (Approaches A and B) on attitude, knowledge, simulated achievement, and laboratory achievement of fourth, fifth and sixth grade elementary school students who were studying SI measurement. The instructional approaches identified were:

1. Approach A (laboratory activity) provided instruction by having students physically measure three-dimensional objects with metric scales; and
2. Approach B (simulated activity) provided instruction by having students identify measurements from pictures of two-dimensional objects along side of which metric scales had been printed.

Because of the nature and design of the experiment, the analysis of covariance through multiple regression was used to analyze all posttest and retention test data. However, before applying this statistical procedure the researcher first established the homogeneity of regression coefficients between groups. This preliminary procedure was necessary before testing whether or not significant differences existed between the treatment groups.

Hypotheses were stated and tested to answer questions concerning the effects of instructional approaches and test types upon student attitude, knowledge, achievement, and retention. All hypotheses were tested at the .05 level of confidence.

The homogeneity of regression coefficients procedure for checking the effect of attitude toward the International System of Units, prior knowledge of SI measurement, and mental ability on scores students received on the simulated section and laboratory section of the achievement test revealed a significant difference between the approaches on the laboratory section of the achievement test at the sixth grade level. This finding prompted the researcher to further analyze the achievement data by level of mental ability in an effort to isolate this difference.

The homogeneity of regression procedure was used to analyze the sixth grade data which revealed that there was no significant difference in group mean post or retention achievement scores of high ability sixth grade students exposed to Approach A or Approach B, as well as their low ability sixth grade counterparts.

The homogeneity of regression procedure was also used to check the effect of attitude toward the International System of Units, prior knowledge of SI measurement, and mental ability on scores students received on all other posttest and test of retention measures. This procedure revealed a number of significant differences between approaches, a summary of which follows: (1) the simulated section of the achievement test was preferred over its laboratory section counterpart as assessed from posttest data, (2) the simulated section of the achievement test was also preferred over its laboratory section counterpart as assessed from test of retention data, (3) the laboratory approach was preferred over its simulated counterpart at the fifth grade level as assessed from test of retention data, and (4) the attitude of sixth grade students who studied by the laboratory approach was more favorable toward SI measurement than their sixth grade counterparts who studied by the simulated approach as assessed by posttest data.

The combined data of fourth, fifth and sixth grade students by approach also revealed a significant difference in attitude which favored the laboratory approach over the simulated approach to teaching SI measurement.

Teacher attitude was also found to have changed significantly in favor of the International System of Units, although no attempt was made to establish the statistical significance of one approach over the other.

Chapter V

SUMMARY, CONCLUSIONS, IMPLICATIONS, AND PROBLEMS FOR FURTHER STUDY

The purpose of this investigation was to compare the effects of two instructional approaches (Approaches A and B) on attitude, knowledge, laboratory achievement and simulated achievement of fourth, fifth and sixth grade students who were studying SI measurement.

More specifically, the study attempted to provide answers to the following questions:

1. To what extent do Approach A and Approach B affect the attitude of fourth, fifth and sixth grade students who are studying the International System of Units?
2. To what extent do fourth, fifth and sixth grade students who are exposed to Approach A and Approach B increase their knowledge of the International System of Units?
3. To what extent do fourth, fifth and sixth grade students who are exposed to Approach A and Approach B ratain information regarding the International System of Units?
4. To what extent do laboratory and simulated test types affect the achievement of fourth,

fifth and sixth grade students who are studying the International System of Units?

5. To what extent do laboratory and simulated test types affect the retention of fourth, fifth and sixth grade students who are studying the International System of Units?
6. To what extent do Approach A and Approach B affect the attitude of fourth, fifth and sixth grade teachers who are teaching the International System of Units?

The general research hypothesis for this study was that a significant difference would exist in attitude, achievement and retention among fourth, fifth and sixth grade students who have been exposed to the International System of Units by Approach A (laboratory activity) and Approach B (simulation activity). A second research hypothesis for this study was that a significant difference would exist between students' performance on the laboratory section and the simulated section of the achievement test and the test of retention.

Stated in the null form for purposes of statistical treatment, the following hypotheses were tested:

Ho_1: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the attitude scale on the mental ability scores, does not significantly improve the prediction of the scores of the attitude scale over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_2: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the cognitive achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_3: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_4: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the achievement test on the mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the achievement test over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_5: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_6: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_7: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the achievement test after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_8: No significant difference exists between the scores students received on the laboratory section and the simulated section of the achievement test, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_9: No significant interaction exists between the scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{10}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the cognitive retention test on mental ability scores, does not significantly improve the prediction of the scores of the cognitive retention test over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_{11}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the simulated section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the simulated section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_{12}: The use of separately derived regression coefficients for Approaches A and B, when regressing the scores of the laboratory section of the test of retention on mental ability scores, does not significantly improve the prediction of the scores of the laboratory section of the test of retention over the use of a common regression coefficient when pretest scores are held constant for grade four, five and six.

Ho_{13}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the scores of the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{14}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of the laboratory and simulated sections of the test of retention after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{15}: No significant difference exists between the scores students received on the laboratory section and the simulated section of the test of retention, regardless of the instructional approach, after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{16}: No significant interaction exists between the retention scores students received on instructional approaches and test types, after initial knowledge of the International System of Units and mental ability are held constant for grade four, five and six.

Ho_{17}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of all fourth, fifth and sixth grade students on the attitude scale after initial attitude toward the International System of Units, initial knowledge of the International System of Units and mental ability are held constant.

Ho_{18}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of all fourth, fifth and sixth grade students on the cognitive achievement test after initial knowledge of the International System of Units and mental ability are held constant.

Ho_{19}: No significant difference exists between students receiving instruction by Approach A and those receiving instruction by Approach B as measured by the combined scores of all fourth, fifth and sixth grade students on the cognitive retention test after initial knowledge of the International System of Units and mental ability are held constant.

Ho_{20}: No significant difference exists between teachers who taught the International System of Units by Approach A and those who taught by Approach B as measured by the scores of the attitude scale after initial attitude toward the International System of Units was held constant.

Summary

This investigation was conducted as a quasi-experimental non-equivalent control group design in which a comparison was made between two approaches to teaching the International System of Units. Permission to conduct the investigation was obtained from the Warrensburg R-VI Board of Education during the Spring of 1974. The researcher then selected the elementary schools, teachers, fourth, fifth and sixth grade classes for participation in the investigation. Since it was not possible to randomly assign students to treatments, the researcher accepted intact groups as scheduled and randomly assigned treatments to groups. Initial status of the treatment groups was established using the following variables: (1) mental ability as measured by the Henmon-Nelson Test of Mental Ability (Form 1), attitude toward the International System of Units as measured by a researcher-designed and prepared attitude scale, and (3) knowledge of the International System of Units as measured by a researcher-designed and prepared cognitive instrument. All of these measures were used as covariates to adjust for initial differences which might exist between the two treatment groups.

Prior to this investigation the researcher developed a set of instructional objectives based on the cognitive domain. These objectives were used as the basis for the: (1) development and preparation of instructional materials, (2) development and preparation of evaluation instruments, and (3) adaptation of the slide/tape series used in the study.

The instructional materials, evaluation instruments, and slide/tape series were evaluated by a panel of judges. These items were then subjected to a pilot study during the Spring of 1975, prior to their adoption for utilization in the investigation.

The actual experiment was conducted over a three week period beginning April 4, 1975, and ending on April 25, 1975. Student experiences within one treatment group were based on laboratory activities (Approach A), while experiences for the other treatment group were based on simulated activities (Approach B). Upon completion of the treatments, the students were given a researcher-prepared post attitude scale, cognitive test and achievement tests. Tests of retention over cognitive and achievement concepts were administered three weeks later on May 15 and 16, 1975.

The analysis of covariance through multiple regression procedure was the primary research technique used to analyze attitude, cognitive and achievement post and retention measures. All hypotheses were tested at the .05 level of confidence.

The homogeneity of regression coefficients procedure for checking the effect of attitude toward SI measurement, knowledge of SI measurement, and mental ability on scores students received on the post attitude scale (Ho_1) revealed no significant difference between approaches at any grade level.

The homogeneity of regression coefficients procedure was also used for checking the effect of prior knowledge of SI measurement and mental ability on scores students received on the cognitive posttest (Ho_2). This procedure revealed no significant difference between approaches at any grade level.

The homogeneity of regression coefficients procedure for checking the effect of prior knowledge of SI measurement and mental ability on scores students received on the simulated section (Ho_3) and laboratory section (Ho_4) of the achievement test revealed a significant difference between approaches on the laboratory section of the achievement test at the sixth grade level only. This finding prompted the researcher to further analyze the achievement data for sixth grade students by level of mental ability and prior knowledge of SI measurement in an effort to isolate this difference.

A statistical analysis, based on the results of (Ho_1), revealed a significant difference in group mean post attitude scores of sixth grade students favoring Approach A, the laboratory approach (Ho_{5-6}). Significant differences in post attitude were not identified for their fourth and fifth grade counterparts (Ho_{5-4}) and (Ho_{5-5}). A statistical analysis, based on the results of (Ho_2), revealed no significant difference in group mean post cognitive scores of students studying by Approaches A and B, at any grade level (Ho_6).

A statistical analysis, based on the results of (Ho_3) at the fourth and fifth grade levels, failed to reveal a significant difference in the group mean post achievement scores of students studying by Approaches A and B (Ho_7). A statistical analysis, resulting from the significance found in (Ho_3) at the sixth grade level, failed to reveal a significant difference in the group mean post achievement scores of high ability (Ho_{7-6-H}) sixth grade students studying by either Approach A or Approach B, as well as their low ability (Ho_{7-6-L}) counterparts.

A statistical analysis, based on the results of (Ho_4) at the fourth and fifth grade levels, failed to reveal a significant difference in group mean post laboratory achievement scores of students studying by Approaches A and B (Ho_8). A statistical analysis, resulting from the significance found in (Ho_4) at the sixth grade level, revealed a significant difference in the achievement scores of both high ability (Ho_{8-6-H}) and low ability (Ho_{8-6-L}) sixth grade students on the laboratory section of the achievement test and their scores on the simulated section of the achievement test. The significant difference favored the simulated section of the achievement test.

A statistical analysis, based on the significant difference of (Ho_3) and (Ho_4), failed to reveal a significant interaction of approaches and test types (Ho_9) at any grade level as measured by the researcher-prepared post achievement test.

The homogeneity of regression coefficients procedure was used for checking the effect of prior knowledge of SI measurement and mental ability on scores students received on the cognitive test of retention (Ho_{10}). This procedure revealed no significant difference between approaches at any grade level.

The homogeneity of regression coefficients procedure was also used for checking the effect of prior knowledge of SI measurement and mental ability on scores fourth, fifth and sixth grade students received on the simulated section (Ho_{11}) and laboratory section (Ho_{12}) of the achievement test of retention. This procedure revealed no significant difference between approaches on either section of the achievement test of retention at any grade level.

The statistical analysis, based on the results of (Ho_{10}), failed to reveal a significant difference in group mean cognitive test of retention scores of fourth, fifth and sixth grade students studying by Approaches A and B (Ho_{13}).

A statistical analysis, based on the results of (Ho_{11}), failed to reveal a significant difference in group mean achievement test of retention scores of fourth, fifth and sixth grade students studying by Approaches A and B (Ho_{14}).

A statistical analysis, based on the results of (Ho_{12}), revealed a significant difference in the achievement retention test scores of fourth, fifth and sixth grade students on the laboratory section of the retention test and their score on the simulated section of the retention test (Ho_{15}). The significant difference favored the simulated section.

A statistical analysis, based on the results of (Ho_{11}) and (Ho_{12}), failed to reveal a significant interaction of approaches and test types (Ho_{16}) at any grade level as measured by the researcher-prepared achievement test of retention.

A statistical analysis, based on combined grade level data on the post attitude scale (Ho_5), revealed a significant difference for approaches (Ho_{17}). The significant difference favored Approach A, the laboratory approach.

A statistical analysis, based on the combined grade level data on the cognitive posttest (Ho_6) and the cognitive test of retention (Ho_{13}), failed to reveal a significant difference for approaches on the combined post cognitive data (Ho_{18}) or the combined cognitive test of retention data (Ho_{19}).

A t-test, applied to the difference between pre and post attitude measures of the twelve teachers involved in both approaches used in the study, revealed a significant difference in favor of SI measurement by those teachers who taught using Approach A as well as those who taught using Approach B.

Conclusions

To the extent that the data and findings resulting from the research procedure employed in this study are valid and representative of fourth, fifth and sixth grade students in similar metropolitan areas and that the assumptions made were valid, some conclusions may be drawn. However, in considering the conclusions of this study, certain factors should be kept in mind.

Prior to making an analysis of fourth, fifth and sixth grade student posttest and test of retention measures, it became necessary to ascertain homogeneity of the intact groups. This analysis revealed a significant difference between groups of sixth grade students on their achievement of the laboratory section of the achievement test. As a result of this finding, it was concluded that the difference in sixth grade student scores on the laboratory section of the instrument could be attributed to differing levels of mental ability. The conclusions which are made with respect to the achievement of sixth grade students in this study are therefore based on high and low mental abilities.

When comparisons were made between the laboratory approach (Approach A) and the simulated approach (Approach B) on the post attitude measure, the findings revealed that a significant difference did exist among group mean scores of sixth grade students, but not for their fourth or fifth grade counterparts. Therefore, it may be concluded that, under the conditions of this experiment, sixth grade students who experience both the laboratory and simulated approaches to SI measurement will exhibit a greater differential effect favoring the laboratory approach (Approach A).

The findings of this investigation failed to reveal a significant difference in the effect of Approach A (laboratory activities) and Approach B (simulated activities) on group mean cognitive posttest and test of retention measures for students at any grade level. Therefore, it may be concluded that, under the conditions of this investigation, there will not be a differential effect upon post cognitive knowledge and retention of that knowledge by fourth, fifth and sixth grade students as a result of exposure to the laboratory approach (Approach A) or the simulated approach (Approach B) to studying SI measurement.

The findings of this investigation also failed to reveal a significant difference in the effect of Approach A (laboratory activities) and Approach B (simulated activities) on group mean scores of SI measurement for high ability sixth grade students as well as their low ability sixth grade counterparts. The same findings were revealed at the fourth and fifth grade levels although levels of mental ability were not taken into consideration. It was also ascertained that the effects of Approach A to Approach B upon informational retention were not significantly different for any of the three grade levels. Therefore, it may be concluded that, under the conditions of this investigation, there will not be a differential effect upon the informational achievement and retention of fourth, fifth and sixth grade students as a result of exposure to the laboratory approach (Approach A) or the simulated approach (Approach B) to studying SI measurement.

When comparisons were made between the laboratory and simulated sections of the achievement and retention tests, the findings revealed that a significant difference did exist among group mean scores of fourth, fifth and sixth grade students, regardless of their mental ability level. Therefore, it may be concluded that, under the conditions of this experiment, fourth, fifth and sixth grade students who experience both the simulated and laboratory sections of the achievement and retention tests will exhibit a greater differential effect favoring the simulated section of the test.

The findings of this investigation failed to reveal a significant interaction between instructional approaches and test types at all grade levels, regardless of levels of mental ability. Therefore, it may be concluded that, under the conditions of this experiment, there is no significant interaction between instructional approaches and laboratory and simulated test types that affect the ability of fourth, fifth and sixth grade students to make SI measurements.

When comparisons were made between the teachers who presented SI measurement by the laboratory approach (Approach A) and the simulated approach (Approach B) on the post attitude measure, the findings revealed that a significant difference did exist among the group mean scores of the twelve teachers. Therefore, it may be concluded that, under the conditions of this experiment, fourth, fifth and sixth grade teachers who experience either the laboratory or simulated approach toward SI measurement will exhibit a differential effect favoring SI measurement.

Implications

In view of the findings and conclusions of this study, the following implications are presented:

Assuming that this study can be replicated with similar results of no difference in the laboratory approach (Approach A) or simulated approach (Approach B) to studying SI measurement, either approach would appear to be beneficial. Thus, educators involved in the teaching of SI measurement should explore the possibility of utilizing either or both approaches.

Since sixth grade students, plus all students when grade levels were combined, experiencing the laboratory approach (Approach A) exhibited a more favorable attitude toward SI measurement than did those students who experienced the simulated approach (Approach B), educators should take this into consideration when selecting an approach to present SI measurement concepts.

Since students experiencing the simulated section of the instrument achieved at a higher level than they did on the laboratory section of the instrument, educators should take this into consideration when testing SI measurement concepts. A close examination of group mean scores reveals that it may be desirable to utilize simulated test items prior to the utilization of laboratory items.

Since the analysis revealed no significant difference in high or low ability students to achieve and retain SI measurement concepts, it appears that educators should explore the possibility of utilizing either or both approaches when teaching SI measurement to high or low mental ability levels.

Since the teachers who experienced the laboratory approach (Approach A) and the simulated approach (Approach B) both exhibited a favorable attitude toward SI measurement, it would appear that either or both approaches might be used to teach SI measurement. A close examination of group mean scores, though, does reveal that there is a much higher level of significance favoring the laboratory approach (Approach A).

Problems for Further Study

During the course of this study several related problems emerged that warrant further research. They are as follows:

1. What effect would the laboratory approach or simulated approach to teaching SI measurement have upon the achievement of students in grades four through six if the concepts of the International System of Units are infused with both science and mathematics concepts?
2. What effect would the laboratory approach or simulated approach have if students were grouped according to other classification variables than those used in this study?
3. What effect does estimating measurements have upon the learning of SI units of measure?
4. Would the use of laboratory or simulated SI problems reveal a difference in time for execution, number of solutions obtained, and anxiety levels of particular SI problems?
5. What effect would the use of other types of instructional media to teaching SI measurement than were used in this study have upon student attitude and achievement?
6. Could the permanency of attitude and knowledge of SI measurement be improved by increasing the time interval between the posttest and the test of retention by allowing more than three weeks between these measures?

7. What effect would the utilization of one test type as opposed to the two types used in this study, have upon the achievement and retention of attitude toward and knowledge of SI measurement?

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APPENDIX A

Composite Scores for Grades Four, Five and Six

Approach A--Laboratory

Approach B--Simulated

COMPOSITE SCORES FOR GRADE FOUR APPROACH A--LABORATORY

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
54	130	7	10	11	18	15	9	9	9	9
69	126	18	25	14	24	23	10	9	7	7
55	123	12	31	5	19	17	10	10	9	9
64	122	10	14	11	18	16	9	10	6	8
8	122	10	14	11	18	16	9	9	7	8
1	119	18	22	8	17	17	9	7	6	8
67	119	18	22	8	17	17	8	8	7	5
15	118	9	8	8	13	13	10	8	9	6
21	117	12	14	8	18	14	8	10	7	8
62	114	11	12	7	17	15	10	9	8	8
6	112	6	14	8	8	10	4	4	6	5
5	112	10	12	7	15	12	4	7	5	9
75	112	6	11	5	13	15	7	7	6	8
20	111	9	13	7	14	9	9	8	6	9
4	111	11	15	4	11	15	10	8	8	9
2	111	9	2	7	9	12	7	8	7	5

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COMPOSITE SCORES FOR GRADE FOUR APPROACH A--LABORATORY (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
71	111	10	5	8	13	20	10	10	7	8
22	110	6	12	8	11	10	8	8	7	8
19	109	10	9	5	7	11	8	9	8	7
17	109	14	15	11	17	21	10	9	8	8
14	108	7	18	6	8	15	8	8	4	8
72	107	15	19	4	18	13	4	7	5	7
68	106	11	14	10	11	11	10	9	7	7
9	104	7	11	8	6	8	2	7	4	4
53	104	13	30	14	16	17	9	9	7	7
57	104	15	13	6	13	15	9	9	8	8
18	102	16	14	7	12	12	8	7	6	7
10	102	7	11	7	12	10	9	6	3	5
16	96	7	5	6	9	14	4	4	7	7
65	95	11	4	8	15	11	8	9	5	7
61	93	7	10	10	14	15	8	8	8	8
7	92	9	4	10	17	19	8	8	7	7

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COMPOSITE SCORES FOR GRADE FOUR APPROACH A--LABORATORY (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
3	90	10	18	3	9	7	6	8	6	5
12	90	19	13	10	14	15	7	8	7	6
60	89	5	12	3	8	8	8	6	6	7
52	87	17	16	5	5	7	6	7	6	8
70	87	15	13	4	8	7	4	2	5	3
66	85	7	6	4	9	9	5	4	2	5
73	83	1	5	2	7	7	6	4	4	4
13	75	11	6	7	5	6	6	3	4	4
51	72	8	17	3	8	6	3	8	2	4
Mean	104.61	10.17	12.8	7.05	12.37	12.8	7.49	7.51	6.24	6.83
S.D.	13.84	4.06	6.28	2.95	4.39	4.15	2.2	1.95	1.72	1.64

COMPOSITE SCORES FOR GRADE FOUR APPROACH B--SIMULATED

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section Posttest Score	Simulated Section Retention Score	Laboratory Section Posttest Score	Laboratory Section Retention Score
566	143	16	28	13	24	20	10	10	9	7
527	139	9	19	16	24	20	10	9	9	8
563	137	16	21	14	27	22	9	8	9	9
519	135	16	27	12	23	23	10	9	9	10
551	133	11	16	5	14	16	9	8	8	8
502	130	13	20	13	23	18	10	10	7	10
561	129	10	2	15	27	23	8	8	8	9
504	126	6	19	13	24	23	10	10	7	7
562	126	12	5	8	20	8	10	10	8	10
556	125	8	6	11	18	18	7	7	8	8
523	125	13	3	11	19	18	10	8	8	8
571	125	16	29	12	25	21	9	9	8	9
560	124	9	17	7	12	13	9	9	8	9
512	123	6	1	6	12	13	9	9	5	8
516	122	8	6	6	16	15	8	8	6	9
509	122	15	28	10	29	25	9	9	8	5

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COMPOSITE SCORES FOR GRADE FOUR APPROACH B--SIMULATED (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
522	120	17	30	11	19	16	10	8	7	8
520	118	4	20	8	17	16	9	9	10	8
506	118	10	29	9	20	16	8	9	7	9
511	117	8	5	7	16	18	9	10	9	10
507	115	15	25	13	25	23	9	9	9	9
552	114	4	9	8	14	12	10	10	10	9
569	114	13	18	14	17	15	9	8	10	9
513	114	5	6	6	15	15	8	7	6	6
554	114	9	19	16	28	26	9	10	9	9
505	111	15	22	6	13	18	6	8	7	6
508	111	14	3	8	12	8	9	8	6	8
568	110	9	20	6	15	11	8	8	10	8
558	107	7	12	11	19	22	9	10	8	9
573	107	12	8	11	20	18	9	10	10	8
515	106	6	13	8	10	11	8	7	7	7
501	106	11	4	8	12	14	8	7	4	9

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COMPOSITE SCORES FOR GRADE FOUR APPROACH B--SIMULATED (Con

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Posttest Score	Se Rete Sc
565	105	12	13	8	13	14	7	
503	104	10	6	7	16	15	10	
557	102	4	6	12	21	21	10	1
529	100	13	12	6	13	17	9	1
518	98	7	10	9	7	9	8	
555	94	13	20	5	8	8	6	
514	93	5	2	6	5	7	6	
553	88	14	5	8	9	12	6	
517	85	12	19	8	10	10	7	
575	69	9	16	5	7	8	5	
Mean	104.61	10.17	12.8	7.05	12.37	12.8	7.49	7.
S.D.	13.84	4.06	6.28	2.95	4.39	4.15	2.2	1.

COMPOSITE SCORES FOR GRADE FIVE APPROACH A--LABORATORY

							Simulated Section		Laboratory Section	
Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Posttest Score	Retention Score	Posttest Score	Retention Score
261	143	16	27	16	27	24	27	27	27	24
258	143	19	30	14	23	24	27	27	23	18
207	132	13	15	7	21	19	27	26	24	25
205	129	16	20	14	20	19	22	26	22	26
209	128	10	13	12	19	23	27	26	26	25
273	127	19	28	19	27	26	27	25	26	27
216	127	6	4	6	14	16	25	27	24	20
220	125	12	26	6	15	15	23	26	24	23
262	125	15	7	7	12	15	27	27	23	24
259	124	18	27	3	18	15	27	26	23	27
260	122	13	15	16	16	15	27	27	22	25
270	119	8	13	11	13	12	21	19	17	20
223	118	10	10	13	26	22	24	25	25	25
217	118	10	14	7	10	13	23	24	19	22
222	117	13	20	4	9	10	24	27	25	27
213	117	17	19	7	20	19	27	27	27	23

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COMPOSITE SCORES FOR GRADE FIVE APPROACH A--LABORATORY (Continued)

							Simulated Section		Laboratory Section	
Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Posttest Score	Retention Score	Posttest Score	Retention Score
253	116	11	18	14	23	23	26	26	21	24
263	115	13	28	8	24	18	27	25	25	26
257	115	14	26	12	26	20	24	27	24	20
206	115	12	17	10	20	22	27	27	27	27
214	114	10	16	11	13	15	26	26	22	26
203	109	12	9	9	19	17	24	23	21	24
210	108	9	16	11	15	17	25	26	17	19
212	108	10	8	9	8	13	14	26	17	24
255	108	17	29	4	14	17	23	27	25	24
252	107	11	22	9	6	11	23	23	26	17
275	106	7	7	4	12	9	16	17	16	27
268	106	12	14	11	12	12	24	27	22	23
254	106	11	13	12	14	15	25	26	23	21
256	106	11	11	9	12	14	27	27	15	26
208	106	13	27	8	14	12	25	27	23	23

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COMPOSITE SCORES FOR GRADE FIVE APPROACH A--LABORATORY (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section Posttest Score	Simulated Section Retention Score	Laboratory Section Posttest Score	Laboratory Section Retention Score
201	106	8	8	12	13	18	25	25	26	23
204	105	15	9	8	11	12	20	23	14	24
202	105	8	16	10	12	12	20	16	18	25
264	105	9	14	6	10	7	18	25	16	24
221	99	6	14	9	9	16	19	23	18	24
219	98	11	7	8	8	5	19	20	14	19
265	96	15	9	7	14	8	23	21	13	14
267	95	15	29	5	14	13	21	24	19	16
224	68	17	14	6	9	12	12	8	7	8
269	67	8	16	7	8	8	11	13	4	14
Mean	112.27	12.2	16.71	9.29	15.37	15.44	23.15	24.15	20.73	22.76
S. D.	15.17	3.45	7.36	3.6	5.74	4.97	4.17	4.15	5.26	3.50

COMPOSITE SCORES FOR GRADE FIVE APPROACH B--SIMULATED

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
714	137	16	20	18	26	22	27	25	26	25
708	134	15	28	18	24	26	25	26	23	26
704	132	18	27	14	24	20	24	22	23	26
716	129	12	23	16	19	16	26	26	25	26
711	129	16	23	19	25	23	24	27	25	24
755	125	13	28	13	20	17	26	25	25	25
751	124	12	2	12	20	19	27	27	24	16
767	122	17	22	15	20	22	27	25	23	24
766	120	12	20	13	24	23	26	27	25	27
703	119	17	30	16	21	19	25	27	22	23
723	119	10	4	7	12	13	27	22	12	18
761	118	12	2	5	13	14	24	22	22	19
719	118	17	27	15	20	20	25	26	26	24
763	116	14	21	8	10	8	23	24	17	25
752	115	11	26	7	15	10	22	20	18	22
754	114	11	23	14	14	21	25	27	23	23

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COMPOSITE SCORES FOR GRADE FIVE APPROACH B--SIMULATED (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section Posttest Score	Simulated Section Retention Score	Laboratory Section Posttest Score	Laboratory Section Retention Score
764	114	11	2	9	13	15	24	25	23	23
756	114	19	23	7	19	21	24	26	20	23
712	113	8	13	9	10	16	23	21	19	19
713	113	12	12	12	15	14	24	26	20	25
706	111	6	9	6	16	17	22	24	22	19
717	111	12	27	14	28	27	26	25	27	24
702	110	6	16	6	12	9	26	21	19	23
709	109	9	4	13	7	10	21	25	22	24
758	107	10	13	10	13	8	17	21	18	21
771	105	12	4	8	17	12	24	26	22	23
765	102	9	7	6	15	15	16	16	16	20
707	102	13	2	10	14	13	22	22	22	24
705	101	12	22	10	10	9	22	24	19	18
710	100	9	7	9	13	14	16	19	17	22
760	93	12	20	10	13	16	22	25	20	24

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COMPOSITE SCORES FOR GRADE FIVE APPROACH B--SIMULATED (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
718	93	14	16	4	8	4	16	16	12	15
715	91	8	9	4	5	10	16	23	19	18
759	90	10	8	11	9	10	26	19	22	15
701	88	6	12	6	5	9	23	18	7	15
721	88	11	10	5	6	10	19	20	17	20
773	88	9	22	7	12	14	19	15	18	16
768	87	5	5	10	6	7	18	25	16	23
720	83	11	8	8	3	7	10	9	8	7
769	77	7	8	4	2	10	9	14	7	11
757	77	9	12	10	6	8	13	10	12	11
Mean	108.24	11.54	15.05	10.2	14.24	14.59	21.95	22.27	19.59	20.88
S.D.	15.65	3.42	8.8	4.09	6.65	5.68	4.58	4.54	5.07	4.59

COMPOSITE SCORES FOR GRADE SIX APPROACH--LABORATORY

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated	Se
							Posttest Score	Rete Sc
405	134	14	29	9	20	18	24	2
412	129	11	17	5	18	16	26	2
428	127	9	22	9	28	28	27	2
409	124	10	17	13	24	17	22	2
475	124	8	24	10	21	22	26	2
454	122	6	17	11	17	18	25	2
451	121	10	20	15	28	24	27	2
469	121	11	32	12	22	21	26	2
416	121	13	26	12	19	16	27	2
452	118	12	26	10	18	16	26	2
420	118	12	4	10	16	24	27	2
462	115	17	29	8	19	16	26	2
464	115	8	16	4	17	14	23	2
472	115	13	28	7	17	15	27	26

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COMPOSITE SCORES FOR GRADE SIX APPROACH--LABORATORY (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
458	114	8	24	4	19	23	27	26	27	24
465	114	15	31	13	16	22	25	26	24	24
466	114	11	20	9	19	16	27	25	23	26
424	113	7	16	5	17	19	27	27	25	26
460	112	10	19	7	24	18	27	27	27	26
471	112	10	19	5	22	20	27	27	24	25
476	112	6	21	12	20	21	27	24	24	26
453	109	12	7	9	14	18	25	25	23	23
455	108	12	20	9	20	17	26	25	21	25
413	107	6	11	10	22	22	27	26	27	25
474	105	12	31	13	19	18	26	25	22	22
468	104	7	29	7	11	15	18	22	15	20
403	103	18	32	4	15	14	21	25	18	18
415	103	8	10	8	18	17	26	27	24	26
422	101	10	12	11	14	11	18	25	21	19

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COMPOSITE SCORES FOR GRADE SIX APPROACH--LABORATORY (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
418	100	7	21	8	19	16	18	24	10	24
463	100	13	29	6	14	12	27	26	25	26
406	99	8	24	4	20	17	26	26	22	24
419	98	10	16	11	22	8	19	15	23	21
461	97	14	21	5	16	13	24	24	16	21
407	95	4	1	8	13	10	19	20	14	17
404	94	4	16	6	13	15	25	23	21	24
459	93	13	17	8	17	18	26	23	18	24
478	86	8	2	6	5	7	21	23	12	16
467	85	10	16	5	9	11	27	23	19	27
473	84	7	8	10	8	5	7	8	10	12
470	79	12	14	6	4	7	14	14	9	6
Mean	108.41	10.15	19.37	8.39	17.41	16.46	24.05	24.37	21.24	22.73
S.D.	12.87	3.17	8.09	2.90	5.11	4.92	4.25	3.82	4.72	4.31

COMPOSITE SCORES FOR GRADE SIX APPROACH B--SIMULATED

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
956	135	15	9	15	22	19	26	24	26	23
909	130	18	29	20	27	27	25	25	23	23
914	124	13	18	12	18	22	26	27	25	27
955	124	9	2	18	23	27	26	26	26	26
965	122	11	5	18	23	26	27	24	20	25
920	120	19	21	20	25	22	27	27	25	27
963	118	10	20	11	24	23	27	23	22	26
953	117	18	27	19	24	25	27	27	26	24
960	117	12	2	11	19	18	27	27	26	27
915	115	8	14	5	13	10	27	18	24	22
924	115	8	21	15	22	21	27	26	21	25
908	113	18	30	12	23	19	17	25	21	23
911	112	17	24	18	23	27	24	27	23	27
916	112	11	17	10	17	19	26	25	22	26
970	109	7	2	7	15	11	22	18	18	22

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COMPOSITE SCORES FOR GRADE SIX APPROACH B--SIMULATED (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
951	108	9	17	16	22	25	27	26	26	27
972	108	16	26	12	16	14	27	27	25	22
922	107	12	4	7	6	9	22	23	20	19
931	107	8	10	12	12	16	27	26	20	25
913	106	6	10	9	17	18	27	27	22	22
952	105	8	3	12	14	10	23	26	20	22
905	105	10	3	9	24	16	27	27	25	27
903	104	10	2	5	12	13	19	23	22	23
954	103	11	3	6	11	12	20	16	23	26
906	102	12	3	12	9	6	23	25	21	18
904	100	9	19	11	6	10	23	14	16	11
907	100	11	1	9	25	25	26	27	23	25
910	98	7	5	4	9	7	26	27	25	23
901	97	9	5	9	12	16	25	27	22	20
976	96	12	2	4	16	11	23	27	22	22

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COMPOSITE SCORES FOR GRADE SIX APPROACH B--SIMULATED (Continued)

Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Simulated Section		Laboratory Section	
							Posttest Score	Retention Score	Posttest Score	Retention Score
975	95	9	21	18	25	13	26	27	24	27
966	94	13	20	8	11	15	25	24	25	24
961	93	14	27	11	22	18	25	19	23	26
959	92	11	7	6	8	6	20	23	18	21
967	91	17	29	13	19	19	22	24	23	26
918	90	13	19	8	15	9	18	18	11	13
927	88	8	1	6	14	11	17	21	27	17
957	88	10	15	13	17	19	27	23	16	23
971	88	10	23	10	19	15	26	27	25	26
929	85	15	8	5	7	9	20	27	19	22
912	81	15	10	6	8	5	8	11	7	13
902	79	14	19	15	20	15	27	27	27	26
923	78	12	10	8	8	11	20	25	27	17
925	77	4	5	9	6	7	12	26	18	13
969	68	11	9	8	12	8	10	11	8	9

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COMPOSITE SCORES FOR GRADE SIX APPROACH B--SIMULATED (Continued)

							Simulated Section		Laboratory Section	
Student Number	Mental Ability Score*	Attitude Pretest Score	Attitude Posttest Score	Cognitive Pretest Score	Cognitive Posttest Score	Cognitive Retention Score	Posttest Score	Retention Score	Posttest Score	Retention Score
973	59	6	10	8	12	9	24	20	22	27
Mean	101.61	11.43	12.76	10.87	16.35	15.5	23.33	23.7	21.74	22.5
S.D.	16.06	3.56	9.1	4.46	6.19	6.41	4.61	4.26	4.47	4.61

APPENDIX B

Instructional Objectives for the Study

NOTE: Key to Taxonomy Classification of Cognitive Domain.

1. K. T. - Knowledge of Terminology
2. K. SF. - Knowledge of Specific Facts
3. C. T. - Comprehension--Translation
4. C. I. - Comprehension--Interpretation
5. A. - Application

LINEAR IN SI MEASUREMENT

Taxonomy Classification		The students should be able to:
K. T.	1.	Recall the names of common units of length in the International System of Units.
K. SF.	2.	Identify the centimeter, decimeter, and meter markings on a meter stick.
K. SF.	3.	Identify a local distance of one kilometer.
K. SF.	4.	Recall the symbol for centimeter, decimeter and kilometer.
K. SF.	5.	State the relationships between centimeter, decimeter, meter and kilometer units from a knowledge of the meaning of the prefixes.
C. T.	6.	Identify an object that has a length of one (1) centimeter, (2) decimeter, and (3) meter.
C. T.	7.	Illustrate the relationship that exists between centimeter, decimeter, meter and kilometer units, using the correct symbols.

Taxonomy Classification		
C. I.	8.	Identify additional objects that are either a centimeter, decimeter and meter in length, or multiples thereof.
C. I.	9.	Demonstrate additional relationships that exist between centimeter, decimeter and kilometer units, using the correct symbols.
C. I.	10.	Estimate, in centimeters, the length of common objects, using the correct symbols.
A.	11.	Draw a line segment, in centimeters, of a length specified.
A.	12.	Select the proper units to measure short and long distances.
A.	13.	Measure common objects with rulers or tapes, marked in SI units, to either the nearest centimeter, decimeter, or meter, and record the answer using the correct symbol.

VOLUME (CAPACITY) IN SI MEASUREMENT

Taxonomy Classification		The students should be able to:
K. T.	1.	Recall the names of the common units of volume and capacity in the International System of Units.
K. T.	2.	Distinguish between SI units of volume and capacity.
K. SF.	3.	Recall the symbols for liter, milliliter, cubic centimeter and the cubic cecimeter.
K. SF.	4.	Identify milliliter markings on graduates and containers.
K. SF.	5.	State the relationships between cubic decimeter, liter, cubic centimeter and milliliter.
C. T.	6.	Identify a product that has a volume (capacity) of one (1) cubic decimeter, (2) liter, (3) cubic centimeter, and (4) milliliter.
C. T.	7.	Illustrate the relationship that exists between cubic decimeter, liter, cubic centimeter and milliliter, using correct symbols.

Taxonomy
Classification

C. I. 8. Identify additional products and containers that have a volume (capacity) of one or more (1) cubic decimeter(s), (2) liter(s), (3) cubic centimeter(s), and (4) milliliter(s).

C. I. 9. Demonstrate additional relationships that exist between cubic decimeter, liter, cubic centimeter and milliliter, using correct symbols.

C. I. 10. Estimate the volume (capacity) of containers in cubic decimeters, liters, cubic centimeters and milliliters, using correct symbols.

A. 11. Measure the volume (capacity) of containers to the nearest cubic centimeter, liter, cubic centimeter and milliliter, and record the answer, using correct symbols.

A. 12. Decide whether the volume (capacity) of a container should be measured in cubic decimeters, liters, cubic centimeters, or millimeters.

Taxonomy
Classification

A. 13. Solve simple problems in converting from one SI unit of volume (capacity) to another.

MASS/WEIGHT IN SI MEASUREMENT

Taxonomy Classification	The students should be able to:
K. T.	1. Recall the names of the common units of mass in the International System of Units.
K. SF.	2. Write the correct symbols for SI units of mass.
K. SF.	3. State the relationships between the units of mass from a knowledge of the meaning of the prefixes.
K. SF.	4. Identify the kilogram and gram masses from among a set of standard masses.
K. SF.	5. Recall that the mass of one milliliter of water is about one gram and that one liter of water has a mass of about one kilogram.
C. T.	6. Identify an object that has a mass of approximately one (1) kilogram and (2) gram.
C. T.	7. Illustrate the relationships that exist between kilogram and gram, using the appropriate symbols.

Taxonomy
Classification

C. I. 8. Identify additional objects that have a mass of one or more (1) kilogram(s) and (2) gram(s).

C. I. 9. Illustrate additional relationships that exist between kilogram and gram, using the appropriate symbols.

A. 10. Measure the masses of objects to the nearest kilogram and gram, and record the answer using correct symbols.

A. 11. Decide whether the mass of an object should be measured in grams or kilograms.

A. 12. Solve simple problems in converting from one SI unit of mass to another.

TEMPERATURE IN SI MEASUREMENT

Taxonomy Classification		The students should be able to:
K. T.	1.	Identify the degree Celsius as a metric unit of temperature.
K. SF.	2.	Recall the symbol for degree Celsius.
K. SF.	3.	Identify the degree markings on the Celsius thermometer.
K. SF.	4.	Identify 0°C as the freezing point of water and 100°C as the boiling point of water on the Celsius scale.
C. T.	5.	Identify substances that have a freezing point of 0°C and a boiling point of 100°C.
C. I.	6.	Identify additional substances that have a temperature between 0°C and 100°C.
C. I.	7.	Estimate the temperature of common substances in Celsius units.
A.	8.	Measure the temperature of a given substance to the nearest degree, using the Celsius thermometer, and record his answer using "°C".

APPENDIX C

Scripts for Instructional Lessons

INTRODUCTION TO METRICS

Lesson #I

Slide #	Script
-----	(Music-fades in) (for 10 to 15 seconds)
1	Start (Music-same level)
2	Focus (Music-same level)
3	Metric (Music-same level)
4	Introduction to Metrics (Music-fades)
	Lesson #1
5	EVER SINCE PEOPLE HAVE LIVED ON THE EARTH THEY HAVE RECOGNIZED THE NEED TO MEASURE THINGS. SOMETIMES THE THING TO BE MEASURED WAS A LIQUID SUCH AS GRAPE JUICE.
6	MANY TIMES, THOUGH, IT WAS A DRY MATERIAL SUCH AS CORN.
7	FOR UNITS OF MEASURE OUR ANCESTORS USED WHATEVER WAS HANDY. EARLY UNITS OF MEASURE WERE BASED ON SUCH THINGS AS THE LENGTH OF A FOOT,
8	THE WIDTH OF A FIST, OR
9	THE LENGTH OF THE AREA.
10	THEY ALSO USED SUCH UNITS OF MEASUREMENT AS THE SPAN OF A HAND, A KNOTTED ROPE OR A LENGTH OF WOOD WITH NOTCHES CUT AT EQUAL DISTANCES.
11	TO MEASURE THE VOLUME OF AN OBJECT OR TO MEASURE THE CAPACITY OF AN OBJECT OUR ANCESTORS MAY HAVE USED A CUP, A BOWL OR EVEN A GOURD.
12	TO MEASURE THE MASS OF AN OBJECT, THAT IS, HOW MUCH SOMETHING WEIGHS COMPARED TO SOME KNOWN WEIGHTS, THEY MAY HAVE USED STONES, PEBBLES, OR OTHER SIMILAR OBJECTS.
13	THIS COMMON SYSTEM OF MEASUREMENT PRESENTED MANY PROBLEMS THOUGH BECAUSE EVERYONE DID NOT HAVE THE SAME LENGTH OF FOOT.

14 ALL HANDS, CUPS AND STONES WERE NOT THE SAME SIZE EITHER.

15 THEREFORE, MEASURING WITH ANY DEGREE OF ACCURACY PROGRESSED SLOWLY UNTIL VARIOUS FORMS OF UNIFORM INSTRUMENTATION WERE DEVELOPED, SUCH AS THESE WHICH ARE SHOWN.

16 AS THE NEED TO ACCURATELY MEASURE THINGS INCREASED, SEVERAL COUNTRIES DEVISED THEIR OWN SPECIAL MEASURING SYSTEMS BASED ON VARYING TYPES AND SIZES OF MEASURING UNITS.

17 THE ANCIENT BABYLONIANS USED 60 UNITS AS THE BASE OF THEIR MEASURING SYSTEM, WHILE

18 THE EGYPTIANS USED 10 UNITS AS THEIR BASE,

19 AND THE ROMANS USED 12 UNITS AS THE BASE OF THEIR SYSTEM OF MEASUREMENT.

20 THE ENGLISH SYSTEM, THOUGH, WHICH WAS AGREED UPON AND USED BY MANY PEOPLE IN THE WORLD, USED MANY DIFFERENT TYPES AND SIZES OF MEASURING UNITS WHICH HAD BEEN PRESCRIBED BY THE KING.

21 THIS SYSTEM CONSISTED OF UNITS LIKE THE INCH, THE QUART, AND THE POUND,

22 AND THIS WAS THE SYSTEM OF MEASUREMENT WHICH WAS ADOPTED BY THE UNITED STATES.

23 THIS SYSTEM, LIKE SEVERAL OTHERS, HAD A MAJOR DISADVANTAGE. THERE WAS NO SIMPLE NUMBER PATTERN RELATING ITS VARIOUS UNITS. ONE FOOT CONTAINED 12 INCHES, WHILE 1 YARD CONTAINED 3 FEET.

24 ONE QUART CONTAINED 2 PINTS, WHILE 1 GALLON CONTAINED 4 QUARTS,

25 AND 1 POUND CONTAINED 16 OUNCES.

26 THEREFORE, THE LACK OF A SIMPLE NUMBER PATTERN MADE THE ENGLISH SYSTEM VERY DIFFICULT TO USE, ESPECIALLY WHEN A PERSON WANTED TO COMPARE ONE KIND OF UNIT TO ANOTHER, SUCH AS FINDING OUT HOW MANY PINTS THERE WERE IN A GALLON OR HOW MANY OUNCES THERE WERE IN A QUART.

27 THERE WAS HOWEVER A MEASURING SYSTEM WHICH WAS BUILT UPON A VERY SIMPLE NUMBER PATTERN. THIS MEASURING SYSTEM HAD BEEN DEVELOPED BY THE FRENCH.

28 IT IS THE SYSTEM WHICH WE USE WHEN WE COUNT OR NAME NUMBERS SINCE IT IS BASED ON A PATTERN OF TENS.

29 THIS MEASURING SYSTEM, WHICH USES THE TENS PATTERN, IS BECOMING VERY WIDELY USED THROUGHOUT THE WORLD.

30 THIS SYSTEM OF MEASUREMENT IS REFERRED TO AS THE INTERNATIONAL SYSTEM OF UNITS (SI).

31 ALL OF THE COUNTRIES WHICH ARE SHADED IN RED ARE EITHER MEASURING WITH SI UNITS OR ARE ADOPTING THE SI SYSTEM OF MEASUREMENT. IN FACT, 98% OF ALL THE COUNTRIES IN THE WORLD HAVE GIVEN THEIR COMMITMENT TO ADOPT THE INTERNATIONAL SYSTEM OF UNITS (SI).

32 THE BASIC SI UNIT WHICH IS USED TO MEASURE LENGTH IS THE METER.

33 A METER STICK, WHICH IS USED FOR MEASURING LENGTH IN THE SI SYSTEM, IS SLIGHTLY LONGER THAN A YARD STICK.

34 THE PORTION OF THE METER STICK LYING BETWEEN THE WHITE ARROWS REPRESENTS ONE-TENTH OF A METER WHICH IS WRITTEN 0.1 OR JUST .1 METER.

35 THE PORTION OF THE METER STICK LYING BETWEEN THESE WHITE ARROWS REPRESENTS ONE-HUNDREDTH OF A METER WHICH IS WRITTEN 0.01 OR .01 METER.

36 WHAT PORTION OF THE METER STICK LIES BETWEEN THESE WHITE ARROWS? IF YOUR RESPONSE WAS ONE-THOUSANDTH OF A METER, WHICH WOULD BE WRITTEN 0.001 OR .001 METER, YOU WERE CORRECT.

37 THEREFORE, ALL METRIC UNITS OF LENGTH AND RELATED TO THE METER BY A PATTERN OF TENS, THAT IS, EITHER THEY ARE PARTS OF TEN SUCH AS ONE-TENTH, ONE-HUNDREDTH AND ONE-THOUSANDTH OR THEY ARE MULTIPLES OF TEN SUCH AS TEN, ONE HUNDRED AND ONE THOUSAND.

38 UNITS WHICH ARE SMALLER THAN THE METER ARE SMALLER BY ONE-TENTH WHICH IS WRITTEN .1, ONE-HUNDREDTH WHICH IS WRITTEN .01, AND ONE-THOUSANDTH WHICH IS WRITTEN .001.

39 SIMILARLY, UNITS WHICH ARE LARGER THAN THE METER ARE LARGER BY 10, 100 AND 1000.

40 THE UNITS OF MASS OR WEIGHT ALONG WITH THE METER ARE FUNDAMENTAL UNITS IN THE SI SYSTEM OF MEASUREMENT. THESE UNITS ALONG WITH VOLUME OR CAPACITY WHICH IS A UNIT THAT IS DERIVED FROM THE METER, ARE RELATED BY THE PATTERN OF TENS WHICH WE JUST DISCUSSED.

41 THE CUBE SHOWN IN THIS SLIDE REPRESENTS A UNIT OF VOLUME CALLED A LITER. THE LITER HAS A SLIGHTLY LARGER CAPACITY THAN THE QUART JAR WHICH IS SHOWN ON THE RIGHT.

42 LETS USE THIS CUBE FOR PURPOSES OF CLARIFICATION. THIS CUBE HAPPENS TO BE ONE-TENTH OF A METER WIDE,

43 ONE-TENTH OF A METER LONG,

44 AND ONE-TENTH OF A METER HIGH.

45 LIKE THE METER, THE LITER WAS ALSO DIVIDED INTO SMALLER UNITS REPRESENTING ONE-TENTHS, ONE-HUNDREDTH, AND ONE-THOUSANDTH OF A LITER.

46 THIS TINY CONTAINER HOLDS A VOLUME ONE-THOUSANDTH OF A LITER. EACH OF ITS INSIDE EDGES MEASURES ONE-HUNDREDTH OF A METER. THIS UNIT OF VOLUME OR CAPACITY IS ALSO RELATED TO THE SI UNIT OF MASS OR WEIGHT.

47 THE AMOUNT OF DISTILLED WATER NEEDED TO FILL THE TINY CONTAINER AT STANDARD TEMPERATURE AND BAROMETRIC PRESSURE IS SAID TO HAVE A MASS OF ONE GRAM.

48 THE GRAM, WHICH IS ALSO REPRESENTED BY THE SMALL BRASS CYLINDER, IS AN IMPORTANT UNIT OF MASS.

49 IN THE SAME WAY THAT THE METER AND THE LITER WERE DIVIDED INTO SMALLER UNITS BY A PATTERN OF TENS, THE GRAM WAS ALSO DIVIDED.

50 THE THREE SMALL L-SHAPED PIECES OF METAL REPRESENT ONE-TENTH OF A GRAM WHICH IS WRITTEN 0.1, ONE-HUNDREDTH OF A GRAM WHICH IS WRITTEN 0.01, AND ONE-THOUSANDTH OF A GRAM WHICH IS WRITTEN 0.001.

51 TEMPERATURE IS ANOTHER UNIT THAT WE MEASURE.

52 THE DEGREE CELSIUS WILL BE USED BY MOST PEOPLE AS THE UNIT FOR MEASURING TEMPERATURE. THE DIFFERENCE BETWEEN THE POINT AT WHICH WATER FREEZES ON THE CELSIUS THERMOMETER AND THE POINT AT WHICH WATER BOILS IS DIVIDED INTO 100 EQUAL PARTS.

53 DISTILLED WATER AT STANDARD BAROMETRIC PRESSURE WILL FREEZE AT ZERO DEGREES CELSIUS, AND

54 DISTILLED WATER AT STANDARD BAROMETRIC PRESSURE WILL BOIL AT ONE HUNDRED DEGREES CELSIUS.

55 A COMFORTABLE ROOM TEMPERATURE WILL BE APPROXIMATELY 25 DEGREES CELSIUS, THE NORMAL BODY TEMPERATURE WILL BE APPROXIMATELY 37 DEGREES CELSIUS WHILE A MEAT SUCH AS CHICKEN MAY BAKE AT ABOUT 160 DEGREES CELSIUS IN THE OVEN. MOST MEATS THOUGH WILL COOK AT A MUCH HIGHER TEMPERATURE.

56 AS WAS POINTED OUT EARLIER, THE SI SYSTEM OF MEASUREMENT IS THE MOST WIDELY USED AND MOST EASILY UNDERSTOOD SYSTEM OF MEASUREMENT IN THE WORLD.

57 ONE REASON RELATES TO THE SIMPLICITY OF THE SYSTEM--ONLY A FEW UNITS ARE REQUIRED.

58 ANOTHER IMPORTANT REASON IS THE FACT THAT THE ARITHMETIC INVOLVED ALLOWS YOU TO KEEP THE NUMBERS SIMPLE.

59 THIS LATTER REASON IS PROBABLY THE BIGGEST ADVANTAGE OF THE SI SYSTEM OF MEASUREMENT. THE FACT THAT BOTH LARGE AND SMALL UNITS OF LENGTH, VOLUME OR CAPACITY AND MASS OR WEIGHT ARE RELATED BY THE SAME TENS PATTERN MAKES THIS SYSTEM OF MEASUREMENT IDEAL TO WORK WITH.

60 THE TENS PATTERN IS ALREADY USED BY NEARLY EVERYONE IN THE WORLD FOR COUNTING

61 AS WELL AS FOR WRITING NUMBERS SUCH AS RECORDING VACATION EXPENSES.

62 THE MONEY SYSTEMS OF MOST OF THE NATIONS OF THE WORLD ARE ALSO BUILT UPON THE SAME TENS PATTERN. THE CURRENCY OF THE UNITED STATES SERVES AS AN EXAMPLE.

63 USING THE SI SYSTEM OF MEASUREMENT CAN BECOME AS EASY AS WRITING YOUR NAME OR COUNTING CHANGE, PROVIDED YOU ARE WILLING TO LEARN.

64 End (Music-fades in)

(Music-same level) (for 10 to 15 seconds)

(Music-fades completely out)

PREFIXES AND SUFFIXES IN METRIC MEASUREMENT

Lesson #II

Slide #	Script
-----	(Music-fades in) (for 10 to 15 seconds)
1	Start (Music-same level)
2	Focus (Music-same level)
3	Metric (Music-same level)
4	Prefixes and Suffixes in Metric Measurement (Music fades)
	Lesson #II
5	THE INTERNATIONAL SYSTEM OF UNITS USES A SERIES OF SPECIAL PREFIXES AND SUFFIXES TO DESCRIBE ITS MEASURABLE PROPERTIES.
6	CENTI AND MILLI ARE EXAMPLES OF PREFIXES WHILE THE WORD METER IS AN EXAMPLE OF A SUFFIX.
7	THREE OF THE BASIC SUFFIXES ARE THE METER WHICH IS USED TO INDICATE A MEASURE OF LENGTH, THE LITER WHICH IS USED TO INDICATE A MEASURE OF CAPACITY OR VOLUME AND THE GRAM WHICH IS USED TO INDICATE THE MASS OR THE WEIGHT OF SOMETHING.
8	A PREFIX, ON THE OTHER HAND, IS A GROUP OF LETTERS WHICH ARE PLACED AT THE BEGINNING OF A WORD WHICH CHANGES THE MEANING OF THE WORD. AS YOUR TEACHER SHOWS THESE SLIDES, YOU VIEW THEM. BUT, BEFORE SHOWING THESE SLIDES TO YOU, YOUR TEACHER STUDIED THEM. WE CAN THEREFORE SAY THAT YOUR TEACHER PREVIEWED THE SLIDES.
9	CERTAIN PREFIXES ARE USED TO DESCRIBE LARGE THINGS SUCH AS THE CAPACITY OF A SHIP,
10	WHILE A DIFFERENT SET OF PREFIXES ARE USED TO DESCRIBE SMALL THINGS SUCH AS THE WIDTH OF FILM FOR A CAMERA.
11	THERE ARE SEVERAL PREFIXES WHICH ARE USED IN SI MEASUREMENT OR THE INTERNATIONAL SYSTEM OF UNITS. THREE OF THE MOST COMMON PREFIXES WHICH ARE USED FOR LARGE MEASURES ARE KILO, HECTO, AND DECA.

12 THREE OF THE MOST COMMON PREFIXES WHICH ARE USED FOR SMALL MEASURES ARE DECI, CENTI, AND MILLI.

13 THERE ARE SEVERAL OTHER PREFIXES WHICH ARE USED IN THE METRIC SYSTEM BUT WE WILL ONLY BE USING A FEW OF THOSE WHICH APPEARED ON THE TWO PRECEDING SLIDES.

14 WE WILL BE USING ONLY THE PREFIX KILO WHICH IS USED TO REPRESENT LARGE MEASURES. THE PREFIX KILO IS USED TO INDICATE 1000 OR SOMETHING.

15 WE WILL ALSO BE USING THE PREFIX DECI WHICH IS USED TO REPRESENT SMALL MEASURES. THE PREFIX DECI IS USED TO INDICATE .1 OR ONE-TENTH OF SOMETHING.

16 THE SAME PREFIX MAY BE USED IN CONJUNCTION WITH MORE THAN ONE SUFFIX. THE PREFIX KILO, WHICH IS USED TO INDICATE 1000 OF SOMETHING, WHEN COMBINED WITH THE SUFFIX GRAM REPRESENTS 1000 GRAMS OF MASS OR WEIGHT.

17 THIS SAME PREFIX KILO, WHEN COMBINED WITH THE SUFFIX METER REPRESENTS 1000 METERS OF LENGTH.

18 DIFFERENT PREFIXES MAY ALSO BE USED WITH THE SAME SUFFIX. THE PREFIX KILO WHEN COMBINED WITH THE SUFFIX GRAM REPRESENTS 1000 GRAMS OF MASS OR WEIGHT WHILE THE PREFIX MILLI, WHICH IS USED TO REPRESENT ONE-THOUSANDTH OR .001 OF SOMETHING, WHEN COMBINED WITH THE SUFFIX GRAM REPRESENTS ONE-THOUSANDTH OR GRAMS OF MASS OR WEIGHT.

19 PREFIXES AND SUFFIXES ARE SELDOM WRITTEN OUT IN WORDS AS IS SHOWN HERE BECAUSE THAT WOULD TAKE A LOT OF TIME.

20 A MORE COMMON PRACTICE IS TO USE SYMBOLS TO REPRESENT THE PREFIXES AND SUFFIXES. LETS EXAMINE THE SUFFIXES FIRST. THE SYMBOL FOR THE SUFFIX METER IS THE SMALL LETTER "m", WHILE

21 THE SYMBOL FOR THE SUFFIX LITER IS THE SMALL LETTER "l" AND

22 THE SYMBOL FOR THE SUFFIX GRAM IS THE SMALL LETTERS "gr".

23 THERE ARE TIMES THOUGH WHEN IT IS NECESSARY TO MEASURE LARGE OR SMALL QUANTITIES OF MATERIALS. IN THIS CASE IT WILL BE NECESSARY TO COMBINE A PREFIX SUCH AS DECI, CENTI, MILLI, KILO, OR OTHERS WITH A SUFFIX SUCH AS LITER.

24 YOU WILL RECALL THAT WHEN THE PREFIX KILO WAS COMBINED WITH THE SUFFIX GRAM, IT BECAME A KILOGRAM WHICH IS EQUAL TO 1000 GRAMS.

25 THE SYMBOL FOR KILOGRAM IS THE SMALL LETTERS "kg". THE "k" IS THE SYMBOL USED TO REPRESENT THE PREFIX KILO WHILE THE "g" IS THE SYMBOL USED TO REPRESENT THE SUFFIX GRAM.

26 WHEN A PREFIX SUCH AS DECI IS COMBINED WITH A SUFFIX SUCH AS METER, IT BECOMES A DECIMETER WHICH IS EQUAL TO ONE-TENTH OR .1 METER.

27 THE SYMBOL FOR DECIMETER IS THE SMALL LETTERS "dm". THE "d" IS THE SYMBOL USED TO REPRESENT THE PREFIX DECI WHILE THE "m" IS THE SYMBOL USED TO REPRESENT THE SUFFIX METER.

28 LETS TAKE A FEW MOMENTS TO REVIEW A FEW OF THE IMPORTANT POINTS ABOUT SOME OF THE COMMON SUFFIXES SUCH AS METER, LITER AND GRAM.

29 AS WELL AS A FEW OF THE PREFIXES WHICH ARE USED IN SI MEASUREMENT

30 PREFIXES ARE GROUPS OF LETTERS WHICH ARE PLACED AT THE BEGINNING OF A WORD WHICH CHANGES THE MEANING OF A WORD.

31 ALTHOUGH THERE ARE A NUMBER OF PREFIXES WHICH ARE USED IN THE METRIC SYSTEM, WE ARE ONLY CONCERNED WITH JUST A FEW SUCH AS KILO WHICH REPRESENTS 1000 OR SOMETHING.

32 AND DECI WHICH REPRESENTS ONE-TENTH OR .1 OR SOMETHING.

33 PREFIXES ARE USED IN CONJUNCTION WITH SUFFIXES. THE PREFIX KILO WHEN COMBINED WITH THE SUFFIX GRAM GIVES US A KILOGRAM WHICH IS EQUAL TO 1000 GRAMS,

34 AND THE PREFIX DECI WHEN COMBINED WITH THE SUFFIX METER GIVES US A DECIMETER WHICH IS EQUAL TO ONE-TENTH OR .1 METER.

35 THE SYMBOL FOR KILOGRAM IS "kg,"

36 AND THE SYMBOL FOR DECIMETER IS "dm".

(End 4th grade--start 5th & 6th grades)

37 ADDITIONAL COMBINATIONS OF PREFIXES AND SUFFIXES WILL BE USED IN THE STUDY OF SI MEASUREMENT. THE KILOMETER WHICH WE STUDIED JUST A FEW MOMENTS AGO, IS ONE OF THOSE MEASURES. THE PREFIX KILO WHEN COMBINED WITH THE SUFFIX METER BECOMES A KILOMETER WHICH IS EQUAL TO 1000 METERS.

38 THE SYMBOL FOR KILOMETER IS THE LETTERS "km".

39 TWO PREFIXES WHICH HAVE NOT BEEN STUDIED IN ANY DETAIL ARE CENTI AND MILLI. THESE PREFIXES, ALONG WITH THE PREFIX DECI, ARE USED WHEN SMALL MEASUREMENTS ARE TO BE MADE. CENTI IS USED TO REPRESENT ONE-HUNDREDTH OR .01 OF SOMETHING WHILE MILLI IS USED TO REPRESENT ONE-THOUSANDTH OR .001 OF SOMETHING.

40 AN EXAMPLE MAY SERVE TO FURTHER CLARIFY THIS MEASUREMENT. THE PREFIX CENTI WHICH REPRESENTS ONE-HUNDREDTH OR .01 OF SOMETHING WHEN COMBINED WITH METER GIVES US A CENTIMETER WHICH IS ONE-HUNDREDTH OR .01 METER.

41 THE SYMBOL FOR CENTIMETER IS THE SMALL LETTERS "cm".

42 MILLI IS ALSO A PREFIX WHICH WE WILL BE USING. IF WE COMBINE THE PREFIX MILLI WHICH IS USED TO REPRESENT ONE-THOUSANDTH OF SOMETHING WITH THE SUFFIX GRAM THEN WE HAVE A MILLIGRAM WHICH IS ONE-THOUSANDTH OR .001 GRAMS. THIS IS A VERY SMALL MEASURE OF MASS.

43 THE SYMBOL FOR MILLIGRAM IS THE SMALL LETTERS "mg".

44 LIKEWISE, IF THE PREFIX MILLI IS COMBINED WITH THE SUFFIX LITER WE HAVE A MILLILITER WHICH IS EQUAL TO ONE-THOUSANDTH OR .001 LITER.

45 THIS IS A VERY SMALL MEASURE OF VOLUME OR CAPACITY AS YOU CAN SEE BY THE SMALL CUBE.

46 WHAT WILL THE SYMBOL FOR THE MILLILITER BE?? IF YOU GUESSED THE SMALL LETTERS "ml" YOU ARE CORRECT. HERE WE SEE THE RELATIONSHIP BETWEEN MILLILITERS AND LITERS. IT TAKES 1000 MILLILITERS TO EQUAL ONE LITER.

47 THIS RELATIONSHIP OF TENTHS, HUNDREDTHS, THOUSANDTHS, TENS, HUNDREDS AND THOUSANDS, YOU WILL RECALL FROM THE STUDY OF LESSON #I, IS ONE OF THE BIG ADVANTAGES OF SI MEASUREMENT ALONG WITH THE PREFIXES AND SUFFIXES WHICH WE JUST STUDIED.

48 THIS RELATIONSHIP OF TENS, COUPLED WITH THE PREFIXES AND SUFFIXES WHICH WE JUST STUDIED, WILL MAKE SI MEASUREMENT A VERY EASY SYSTEM OF MEASUREMENT TO LEARN.

49 End (Music fades in)

(Music-same level) (for 10 to 15 seconds)

(Music-fades completely out)

LINEAR

Lesson #III

Slide #	Script
-----	(Music-fades in) (for 10 to 15 seconds)
1	Start (Music-same level)
2	Focus (Music-same level)
3	Metrics (Music-same level)
4	Linear (Music fades)
	Lesson #III
5	THIS LESSON IS ABOUT LINEAR MEASUREMENT OR WE MIGHT SAY THAT IT INVOLVES MEASURING THE LENGTH OF THINGS BY SOME UNIT OF MEASURE.
6	THE BASE UNIT USED TO MEASURE LENGTH IS CALLED THE METER.
7	THE INSTRUMENT USED TO MEASURE METERS IS REFERRED TO AS A METER STICK.
8	A METER STICK, YOU WILL RECALL, IS SLIGHTLY LONGER THAN A YARD STICK.
9	SINCE THE YARD STICK AND THE METER STICK ARE SIMILAR IN SIZE WE MIGHT USE THEM TO MEASURE SOME OF THE SAME THINGS SUCH AS THE WIDTH OF A BOLT OF CLOTH.
10	THE HEIGHT OF A VERY TALL PERSON, WHEN MEASURED WITH A METER STICK, WOULD BE APPROXIMATELY TWO METERS. HIS HEAD WOULD PROBABLY BUMP THE TOP OF MOST DOORS SINCE MOST DOORS ARE TWO METERS HIGH.
11	AN AUTOMOBILE ON THE OTHER HAND WOULD MEASURE APPROXIMATELY FOUR METERS LONG,
12	WHILE A WHALE MIGHT HAVE A LENGTH OF THIRTY METERS.
13	THE SYMBOL FOR THE METER IS THE SMALL LETTER "m".

14 YOU WILL RECALL FROM OUR FIRST AND SECOND LESSONS THAT SI MEASUREMENT UTILIZES A SERIES OF PREFIXES AND SUFFIXES. THE SUFFIX WHICH IS USED TO DENOTE THE LENGTH MEASURE OF ANYTHING IS REFERRED TO AS A METER.

15 THE PREFIXES, WHICH WERE STUDIED IN THE SECOND LESSON, ARE USED WHENEVER IT IS DESIRABLE TO MEASURE THINGS SMALLER OR LARGER THAN A METER, LITER OR GRAM.

16 THERE ARE MANY TIMES WHEN IT IS NECESSARY TO MEASURE THE LENGTH OF THINGS WHICH ARE SMALLER THAN A METER. AN EXAMPLE MIGHT BE THIS BOX,

17 THE LENGTH OF THIS PIECE OF WOOD WHICH HAS A SQUARE CROSS SECTION WILL BECOME AN AXEL FOR THE TWO WOODEN CIRCLES, OR

18 IT MIGHT BE THE LENGTH OF THIS TOY RESCUE VEHICLE.

19 THEREFORE, THE METER IS MANY TIMES DIVIDED INTO SMALLER UNITS FOLLOWING A PATTERN OF TENS, A PRACTICE WHICH IS FOLLOWED THROUGHOUT SI MEASUREMENT.

20 THE METER IS FIRST DIVIDED INTO TEN EQUAL PARTS.

21 EACH OF THESE PARTS IS REFERRED TO AS A DECIMETER.

22 SINCE IT TAKES TEN DECIMETERS TO EQUAL ONE METER, WE SAY THAT A DECIMETER IS EQUAL TO ONE-TENTH OF A METER WHICH IS WRITTEN 0.1 METER.

23 HERE WE SEE A LITTLE MORE THAN ONE DECIMETER. IT IS REPRESENTED AS THE DISTANCE FROM THE END OF THE METER STICK TO THE NUMBER 10, WHICH REPRESENTS ONE-TENTH OR .1 METER.

24 THE LENGTH OF A BOX OF CRAYOLA CRAYONS IS APPROXIMATELY ONE DECIMETER.

25 A DECK OF CARDS WOULD ALSO MEASURE APPROXIMATELY ONE DECIMETER IN LENGTH.

26 A SHEET OF PAPER FROM AN ORDINARY WRITING TABLET IS SLIGHTLY WIDER THAN TWO DECIMETERS AND IS A LITTLE SHORTER THAN THREE DECIMETERS IN LENGTH.

27 THIS TOY CAR, ON THE OTHER HAND, MEASURES SLIGHTLY LONGER THAN TWO DECIMETERS.

28 THE SYMBOL FOR THE DECIMETER IS THE SMALL LETTERS "dm".

29 LETS TAKE JUST A MOMENT TO REVIEW. YOU WILL RECALL THAT A METER STICK IS SLIGHTLY LONGER THAN A YARD STICK,

30 AND THAT THE SYMBOL FOR THE METER, WHICH IS THE SUFFIX USED TO DENOTE THE LENGTH OF SOMETHING, IS THE SMALL LETTER "m".

31 YOU SHOULD ALSO RECALL THAT THE PREFIX DECI IS USED TO REPRESENT ONE-TENTH OF SOMETHING AND THAT IT IS WRITTEN AS .1.

32 IN THIS EXAMPLE, DECI WAS USED TO REPRESENT ONE-TENTH OR .1 METER.

(End 4th grade--start 5th grade) (slide & music)

33 CENTI IS THE NEXT SMALLEST PREFIX WHICH IS USED IN SI MEASUREMENT.

34 IT TAKES TEN CENTIMETERS TO EQUAL ONE DECIMETER.

35 YOU WILL ALSO RECALL THAT IT TOOK TEN DECIMETERS TO EQUAL ONE METER.

36 THEREFORE, IT IS EASY TO SEE THAT IT WILL TAKE TEN TIMES TEN OR ONE HUNDRED CENTIMETERS TO EQUAL ONE METER.

37 IT MIGHT ALSO BE SAID THAT A CENTIMETER IS EQUAL TO ONE-HUNDREDTH OR .01 METER SINCE CENTI IS THE SYMBOL FOR ONE-HUNDREDTH WHICH IS WRITTEN 0.01.

38 ANOTHER EXAMPLE MIGHT PROVIDE FURTHER CLARIFICATION. THE PREFIX CENTI WHICH REPRESENTS ONE-HUNDREDTH OR .01, WHEN COMBINED WITH THE SUFFIX METER GIVES US THE CENTIMETER WHICH REPRESENTS ONE-HUNDREDTH OR .01 METER.

39 A PAPER CLIP MEASURES APPROXIMATELY ONE CENTIMETER IN WIDTH,

40 WHILE A POSTAGE STAMP MEASURES APPROXIMATELY THREE CENTIMETERS IN WIDTH WHICH WOULD BE ABOUT THE SAME WIDTH AS THREE PAPER CLIPS LAID SIDE BY SIDE.

41 THE DIAMETER OF THESE BALLS WOULD ALSO BE GIVEN IN CENTIMETERS.

42 THE SYMBOL FOR THE CENTIMETER IS THE SMALL LETTERS "cm".

43 LETS TAKE JUST A MOMENT TO REVIEW. YOU WILL RECALL THAT THE METER STICK IS SLIGHTLY LONGER THAN A YARD STICK,

44 AND THAT THE SYMBOL FOR THE METER IS THE SMALL LETTER "m".

45 YOU WILL ALSO RECALL THAT THE PREFIX DECI IS USED TO REPRESENT ONE-TENTH OF SOMETHING, IN THIS CASE, ONE-TENTH OF A METER WHICH IS WRITTEN 0.1 METER.

46 AND THAT THE SYMBOL FOR DECIMETER IS THE LETTERS "dm".

47 THE CENTIMETER WAS THE NEXT SMALLEST UNIT STUDIED AND THE PREFIX CENTI IS USED TO REPRESENT ONE-HUNDREDTH OF SOMETHING, WHICH IS WRITTEN .01.

48 HERE WE SEE A CENTIMETER WHICH IS EQUAL TO ONE-HUNDREDTH OR .01 METER. A CENTIMETER IS ILLUSTRATED USING A METER STICK.

49 THE SYMBOL FOR CENTIMETER IS THE LETTERS "cm".

(End 5th grade--start 6th grade) (slides & music)

50 THERE ARE TIMES WHEN IT IS NECESSARY TO MEASURE THINGS WHICH ARE MUCH GREATER THAN A METER. AN EXAMPLE MIGHT BE THE DISTANCE BETWEEN TWO CITIES, SAY DUNKIRK, FRANCE, AND BARCELONA, SPAIN.

51 A COMMON PREFIX WHICH IS USED WHEN YOU ARE TALKING ABOUT LARGE MEASURES SUCH AS LONG DISTANCES IS THE PREFIX KILO.

52 THERE ARE 1000 METERS IN ONE KILOMETER SINCE KILO IS THE SYMBOL FOR ONE THOUSAND. THE PREFIX KILO WHICH REPRESENTS ONE THOUSAND, WHEN COMBINED WITH THE SUFFIX METER GIVES US THE KILOMETER WHICH IS ONE THOUSAND METERS.

53 A VERY COMMON USE OF THE KILOMETER IS TO REPORT DISTANCES ON HIGHWAY SIGNS.

54 A KILOMETER IS A LITTLE OVER ONE-HALF MILE IN LENGTH.

55 THE SPEED AT WHICH AN AIRPLANE TRAVELS WILL BE GIVEN IN KILOMETERS PER HOUR.

56 AND THE SAME KILOMETERS PER HOUR WILL BE USED TO CLOCK THE SPEED OF A TRUCK OR AUTOMOBILE MOVING DOWN THE HIGHWAY.

57 THE SYMBOL FOR THE KILOMETER IS THE SMALL LETTERS "km".

58 MEASURING LENGTH IN THE METRIC SYSTEM WILL REQUIRE THE USE OF A FEW PREFIXES. THE MOST COMMON SYMBOLS WILL PROBABLY BE THE DECI WHICH IS ONE-TENTH OR .1 METER, CENTI WHICH REPRESENTS ONE-HUNDREDTH OR .01 METER AND KILO WHICH IS USED TO REPRESENT 1000 METERS.

59 A LITTLE PRACTICE MEASURING IN SI UNITS WILL ALLOW YOU TO SELECT THE MOST CONVENIENT UNIT FOR MEASURING THE LENGTH OF THIS BOOK,

60 OR THE MOST CONVENIENT UNIT FOR MEASURING THE LENGTH OF THIS PIECE OF LUMBER,

61 OR POSSIBLY IT IS DETERMINING THE SI UNIT TO USE IN MEASURING THE LENGTH AND WIDTH OF A FOOTBALL FIELD.

62 End (Music fades in)

(Music-same level) (for 10 to 15 seconds)

(Music-fades completely out)

VOLUME/CAPACITY

Lesson #IV

Slide #	Script
-----	(Music-fades in) (for 10 to 15 seconds)
1	Start (Music-same level)
2	Focus (Music-same level)
3	Metrics (Music-same level)
4	Volume/Capacity Lesson #IV
5	THE INTERNATIONAL SYSTEM OF UNITS ALSO HAS PROVISIONS FOR MEASURING PROPERTIES OTHER THAN LENGTH WHICH WE JUST STUDIED.
6	THE SPACE INSIDE THIS CONTAINER REPRESENTS ONE OF THE IMPORTANT UNITS OF SI MEASUREMENT. IT IS CALLED VOLUME OR CAPACITY.
7	VOLUME OR CAPACITY IS THE AMOUNT OF A SUBSTANCE OR MATERIAL THAT IS HELD IN A CONTAINER.
8	MEASURES OF VOLUME OR CAPACITY MAY BE USED FOR MEASURING A WET OR LIQUID SUBSTANCE SUCH AS MILK,
9	OR A DRY OR SOLID MATERIAL SUCH AS SALE.
10	ONE OF THE MOST COMMON SI UNITS WHICH IS USED TO MEASURE VOLUME OR CAPACITY IS CALLED THE LITER WHICH YOU WILL RECALL HAS A SLIGHTLY LARGER CAPACITY THAN A QUART JAR.
11	LETS USE A PLASTIC CUBE FOR PURPOSES OF CLARIFICATION. WE WILL ALSO USE A METER STICK TO MEASURE THE SIZE OF THE CUBE.
12	YOU WILL RECALL FROM OUR STUDY OF LENGTH THAT WE FIRST DIVIDED OUR METER STICK INTO TEN EQUAL PARTS.
13	EACH OF THESE 10 PARTS IS REFERRED TO AS A DECIMETER. YOU WILL RECALL FROM OUR STUDY OF LENGTH THAT THE PREFIX DECI IS USED TO REPRESENT ONE-TENTH WHICH IS WRITTEN AS 0.1 METER.

14 THIS LITER CUBE HAPPENS TO BE ONE-TENTH OF A METER WIDE WHICH IS THE SAME THING AS SAYING ONE DECIMETER WIDE,

15 ONE-TENTH OF A METER LONG OR ONE DECIMETER LONG,

16 AND ONE-TENTH OF A METER HIGH WHICH IS THE SAME THING AS ONE DECIMETER HIGH.

17 THE SPACE INSIDE THIS CUBE WHICH MEASURES ONE DECIMETER WIDE BY ONE DECIMETER LONG BY ONE DECIMETER HIGH IS SAID TO HAVE A CAPACITY OR VOLUME OF ONE CUBIC DECIMETER WHICH IS EQUAL TO ONE LITER. THE LITER YOU WILL RECALL IS A LITTLE LARGER THAN A QUART.

18 GASOLINE WILL BE SOLD BY THE LITER INSTEAD OF BY THE GALLON. INSTEAD OF ASKING FOR TEN GALLONS OF GAS YOU WILL ASK FOR FORTY LITERS OF GAS.

19 THE SYMBOL FOR THE LITER IS THE SMALL LETTER "l".

20 IN ORDER TO FIND THE VOLUME OR CAPACITY OF SOMETHING YOU MUST MULTIPLY ITS WIDTH BY ITS LENGTH BY ITS HEIGHT. WHEN THREE THINGS ARE MULTIPLIED TOGETHER IT IS SAID TO BE CUBED. LETS USE A RECTANGULAR SHAPED STACK OF CUBES TO CLARIFY THIS PROCESS. EACH CUBE MEASURES ONE DECIMETER WIDE BY ONE DECIMETER LONG BY ONE DECIMETER HIGH. LETS SEE HOW MANY CUBIC DECIMETERS ARE IN THIS STACK OF CUBES.

21 THE STACK MEASURES FOUR DECIMETERS WIDE BY NINE DECIMETERS LONG BY FOUR DECIMETERS HIGH. FOUR DECIMETERS WIDE BY NINE DECIMETERS LONG EQUALS THIRTY-SIX DECIMETERS. THIRTY-SIX DECIMETERS BY FOUR DECIMETERS HIGH EQUALS ONE HUNDRED AND FORTY-FOUR CUBIC DECIMETERS. REMEMBER, WHEN THREE THINGS ARE MULTIPLIED TOGETHER WE SAY THAT IT HAS BEEN CUBED.

22 LETS TAKE JUST A MOMENT TO REVIEW. YOU WILL RECALL THAT VOLUME OR CAPACITY IS THE AMOUNT OF SUBSTANCE OR MATERIAL THAT IS HELD IN A CONTAINER AND THAT THIS SUBSTANCE OR MATERIAL TO BE MEASURED MAY BE EITHER WET OR DRY.

23 YOU WILL ALSO RECALL THAT THE VOLUME OR CAPACITY OF A SUBSTANCE OR MATERIAL IS FOUND BY MULTIPLYING ITS WIDTH BY ITS LENGTH BY ITS HEIGHT, AND

24 A CUBE WHICH MEASURES ONE DECIMETER WIDE BY ONE DECIMETER LONG BY ONE DECIMETER HIGH IS SAID TO

HAVE A VOLUME OR CAPACITY OF ONE CUBIC DECIMETER WHICH IS EQUAL TO ONE LITER.

25 YOU WILL ALSO RECALL THAT A LITER IS ALMOST THE SAME SIZE AS A QUART. MORE PRECISELY, THE LITER IS A LITTLE LARGER THAN A QUART,

26 AND THAT THE SYMBOL FOR THE LITER IS THE SMALL LETTER "l".

(End 4th grade--start 5th & 6th grades) (slide & music)

27 LIKE THE METER, THE LITER IS MANY TIMES DIVIDED INTO SMALLER UNITS. THE VOLUME OR CAPACITY OF THE CONTAINER ON THE RIGHT IS ONE-TENTH OR 0.1 LITER OF THE LITER CONTAINER SHOWN ON THE LEFT,

28 WHILE THIS EVEN SMALLER CONTAINER IS ONE-HUNDREDTH OR 0.01 LITER.

29 THIS TINY CONTAINER REPRESENTS AN EVEN SMALLER UNIT OF VOLUME OR CAPACITY. IT REPRESENTS ONE-THOUSANDTH OF A LITER WHICH IS WRITTEN 0.001 LITER. IN OTHER WORDS, IT WOULD TAKE 1000 OF THESE TINY CONTAINERS TO EQUAL THE VOLUME OR CAPACITY OF ONE LITER. THIS TINY UNIT OF VOLUME OR CAPACITY IS CALLED A MILLILITER.

30 THE PREFIX MILLI IS USED TO REPRESENT ONE-THOUSANDTH OF SOMETHING WHILE THE SUFFIX LITER TELLS US THAT THE UNIT IS USED FOR MEASURING THE VOLUME OR CAPACITY OF SOMETHING.

31 SINCE THE VOLUME OR CAPACITY OF ONE MILLILITER IS EQUAL TO APPROXIMATELY 25 DROPS OF WATER FROM AN EYE DROPPER, IT BECOMES QUITE OBVIOUS THAT THIS UNIT OF VOLUME OR CAPACITY WOULD BE QUITE IMPRACTICAL TO USE IN FIGURING OUT HOW MUCH WATER A SWIMMING POOL WOULD HOLD.

32 RATHER, THE MILLILITER IS MUCH BETTER SUITED FOR SOMETHING LIKE COOKING. IN FACT, THE MILLILITER IS IDEAL FOR SMALL QUANTITIES WHICH ARE USED IN COOKING SUCH AS SMALL MEASURES OF LEMON JUICE OR VANILLA.

33 MILLILITERS ARE USED PRIMARILY BY SUCH PEOPLE AS CHEMISTS WHO NEED TO MAKE VERY ACCURATE MEASUREMENTS,

34 AND BY DRUGGISTS AS THEY PREPARE A PRESCRIPTION.

35 THE SYMBOL FOR MILLILITER IS THE SMALL LETTERS "ml".

36 LETS TAKE JUST A MOMENT TO AGAIN REVIEW. A LITER, WHICH IS A MEASURE OF VOLUME OR CAPACITY, IS A LITTLE LARGER THAN A QUART.

37 THERE ARE MANY TIMES WHEN IT IS NECESSARY TO MEASURE THE VOLUME OR CAPACITY OF A SUBSTANCE WHICH IS MUCH SMALLER THAN A LITER REGARDLESS OF WHETHER THE MATERIAL WAS WET OR DRY.

38 A VERY CONVENIENT MEASURE TO USE WHERE IT IS NECESSARY TO ACCURATELY MEASURE THE VOLUME OR CAPACITY OF A SUBSTANCE IS THE MILLILITER, AND

39 MILLI IS THE PREFIX WHICH IS USED TO REPRESENT ONE-THOUSANDTH OF SOMETHING WHICH IS WRITTEN AS .001.

40 YOU WILL ALSO RECALL THAT IN ORDER TO DETERMINE THE VOLUME OR CAPACITY OF A SUBSTANCE OR MATERIAL YOU MUST MULTIPLY ITS WIDTH BY ITS LENGTH BY ITS HEIGHT WHICH WILL YIELD ITS CUBIC MEASURE.

41 EVENTUALLY, ALL SUBSTANCES WHICH WILL BE SOLD BY THEIR VOLUME OR CAPACITY WILL BE SOLD BY THE LITER SUCH AS GASOLINE, OR BY A LARGER OR SMALLER SI MEASURE OF THE LITER.

42 End (Music fades in)

(Music-same level) (for 10 to 15 seconds)

(Music-fades completely out)

MASS/WEIGHT

Lesson #V

Slide #	Script
-----	(Music-fades in) (for 10 to 15 seconds)
1	Start (Music-same level)
2	Focus (Music-same level)
3	Metric (Music-same level)
4	Mass/Weight Lesson #V
5	THIS LESSON IS ABOUT MASS AND WEIGHT. WEIGHT IS NOTHING MORE THAN THE GRAVITATIONAL ATTRACTION OF TWO BODIES.
6	THE STRENGTH OR FORCE OF THIS ATTRACTION DEPENDS UPON THE MASS OF THE OBJECTS IN RELATION TO ONE ANOTHER.
7	SINCE THE MOON IS SMALLER THAN THE EARTH, THE MOON IS SAID TO HAVE A SMALLER MASS THAN THE EARTH. THEREFORE, THE MOON HAS LESS ATTRACTION OR GRAVITATIONAL PULL THAN DOES THE EARTH.
8	THIS MEANS THAT A PERSON WHO WEIGHS 100 POUNDS ON THE EARTH WOULD ONLY WEIGH APPROXIMATELY 30 POUNDS ON THE MOON. THE MOON, BEING SMALLER IN MASS THAN THE EARTH HAS LESS GRAVITATIONAL ATTRACTION OR PULL.
9	OUR ASTRONAUTS ARE VERY AWARE OF GRAVITATIONAL ATTRACTION. THEY APPROACH WEIGHTLESSNESS WHILE CIRCLING THE EARTH IN THEIR SPACE CRAFT BUT DO NOT MAINTAIN THIS WEIGHTLESS CONDITION WHEN THEY RETURN TO EARTH. THEREFORE, WE CAN SAY THAT THEIR WEIGHT IS NOT CONSTANT BUT THEIR MASS IS.
10	IN EVERYDAY APPLICATIONS, THOUGH, WE WILL NOT BE CONCERNED WITH WHETHER WE SAY AN OBJECT HAS MASS OR WEIGHS SO MUCH, I.E., AS LONG AS WE STAY FAIRLY CLOSE TO THE EARTH. THEREFORE, THE WORDS MASS AND WEIGHT WILL BOTH BE USED IN THIS LESSON TO DESCRIBE THE SAME THING.

11 THE ORIGINAL BASIS FOR ALL SI MEASURES OF WEIGHT WAS THE GRAM. SINCE IT TAKES 454 GRAMS TO EQUAL ONE POUND, IT IS QUITE OBVIOUS THAT A GRAM IS VERY SMALL.

12 SINCE THE GRAM WAS SO SMALL, IT WAS NOT PRACTICAL TO MEASURE THE WEIGHT OF MANY ITEMS SUCH AS HOW MUCH A PERSON WEIGHED.

13 SINCE THE GRAM WAS SO SMALL, THE KILOGRAM WAS ADOPTED AS THE STANDARD OF WEIGHT. THE KILOGRAM, WHICH IS EQUAL TO APPROXIMATELY 2.2 POUNDS, IS ONE OF THE MOST USEFUL SI UNITS AND IS THE ONLY BASIC UNIT OF SI MEASUREMENT WHICH INCLUDES A PREFIX.

14 THE PREFIX KILO YOU WILL RECALL IS USED TO REPRESENT 1000.

15 THE PREFIX KILO, WHEN COMBINED WITH THE SUFFIX GRAM, GIVES US THE KILOGRAM WHICH IS EQUAL TO 1000 GRAMS.

16 THE SUFFIX GRAM MEANS THAT THE UNIT IS USED TO MEASURE THE WEIGHT OF AN OBJECT.

17 THE BRICK PICTURED HERE WOULD WEIGH APPROXIMATELY ONE KILOGRAM.

18 A DOZEN APPLES WOULD LIKELY WEIGH ONE AND ONE-HALF KILOGRAMS.

19 THIS PUPPY WEIGHS SIX AND ONE-HALF KILOGRAMS,

20 WHILE THE BABY PICTURED HERE WOULD LIKELY WEIGH 7 KILOGRAMS.

21 THE SMALL COLT ON THE OTHER HAND WOULD WEIGH APPROXIMATELY 110 KILOGRAMS.

22 A ROAST MIGHT WEIGH APPROXIMATELY 4 KILOGRAMS, A TALL AND STOUT PERSON MIGHT WEIGH 97 KILOGRAMS, WHILE A CAMPING TRAILER WOULD LIKELY WEIGH 2,600 KILOGRAMS.

23 HOW MUCH DOES THIS HIGH SCHOOL BASKETBALL PLAYER WEIGH?? YOU ARE CORRECT IF YOU SAID THAT HE WEIGHS 75 KILOGRAMS.

24 THE SYMBOL FOR THE KILOGRAM IS THE SMALL LETTERS "kg".

25 LETS TAKE JUST A FEW MOMENTS TO REVIEW. WE SAID THAT WEIGHT WAS NOTHING MORE THAN THE GRAVITATIONAL ATTRACTION OF TWO BODIES AND THAT THE STRENGTH OF THE ATTRACTION DEPENDED UPON THE MASS OF THE BODIES.

26 FOR THIS REASON, MASS IS A BETTER TERM TO USE WHEN DESCRIBING THIS GRAVITATIONAL ATTRACTION RATHER THAN WEIGHT SINCE THE MASS OF A BODY WILL REMAIN VIRTUALLY THE SAME WHEREAS WE KNOW THAT THE WEIGHT OF A MAN ON THE MOON IS MUCH LESS THAN HIS WEIGHT ON THE EARTH.

27 SINCE THE GRAM REPRESENTED SUCH A SMALL MASS, THE KILOGRAM WAS ADOPTED AS THE STANDARD MASS OR WEIGHT SINCE IT REPRESENTED THE MOST USEFUL UNIT OF MASS OR WEIGHT.

28 THE PREFIX KILO IS USED TO REPRESENT 1000 WHILE THE SUFFIX GRAM REFERS TO THE MASS OR WEIGHT OF AN OBJECT,

29 AND THE SYMBOL FOR THE KILOGRAM IS THE SMALL LETTERS "kg".

(End 4th grade--start 5th & 6th grade) (slide & music)

30 THIS SMALL CONTAINER, WHICH IS IN THE SHAPE OF A CUBE, IS CALLED A CUBIC CENTIMETER. IT PLAYS A VERY IMPORTANT PART IN FORMING THE RELATIONSHIP BETWEEN THE METRIC UNITS OF LENGTH, CAPACITY OR VOLUME, AND MASS OR WEIGHT.

31 YOU WILL RECALL THAT THE PREFIX CENTI IS USED TO REPRESENT ONE-HUNDREDTH WHICH IS WRITTEN .01.

32 THE LITTLE CUBE MEASURES ONE CENTIMETER WIDE, ONE CENTIMETER LONG AND ONE CENTIMETER HIGH. YOU WILL RECALL THAT THE VOLUME OR CAPACITY OF THE TINY CONTAINER IS FOUND BY MULTIPLYING ONE CENTIMETER BY ONE CENTIMETER BY ONE CENTIMETER, ITS WIDTH BY ITS LENGTH BY ITS HEIGHT, WHICH GIVES US ONE CUBIC CENTIMETER.

33 IT IS THE CUBIC CENTIMETER WHICH IS USED TO LINK THE SI UNITS OF LINEAR MEASURE WITH THE VOLUME OR CAPACITY MEASURE.

34 THE MASS OF DISTILLED WATER REQUIRED TO FILL A CUBIC CENTIMETER CONTAINER FULL UNDER STANDARD TEMPERATURE AND BAROMETRIC PRESSURE WAS CALLED ONE GRAM. THE GRAM, WHEN FILLED WITH DISTILLED WATER, UNDER STANDARD CONDITIONS, LINKS THE SI UNITS OF MASS, VOLUME AND LINEAR MEASURE.

35 BECAUSE WATER IS AWKWARD TO USE FOR WEIGHING MANY THINGS, SMALL MASS PIECES WERE DEVELOPED. THIS SMALL CYLINDRICAL MASS PIECE HAS THE SAME MASS OR WEIGHT AS THE CUBIC CENTIMETER OF DISTILLED WATER. BOTH HAVE A MASS OF ONE GRAM.

36 EXAMPLES OF COMMON ITEMS WHICH CAN BE REPRESENTED BY THE GRAM WOULD INCLUDE A DIME WHICH HAS A MASS OF APPROXIMATELY 1.8 GRAMS, AN ENVELOPE WHICH WOULD WEIGH APPROXIMATELY 6 GRAMS AND A LARGE CAN OF SOUP WHICH WOULD HAVE A MASS OF APPROXIMATELY 400 GRAMS.

37 THIS PARTICULAR CAN OF SOUP, WHICH IS QUITE SIMILAR TO THE CAN SHOWN IN THE PRECEEDING SLIDE, HAS A SLIGHTLY SMALLER MASS OF ONLY 300 GRAMS WHEREAS THE OTHER CAN WEIGHED 400 GRAMS.

38 THE SYMBOL FOR THE GRAM IS THE SMALL LETTERS "gr".

39 LETS AGAIN TAKE A FEW MOMENTS TO REVIEW. THE MASS OF WATER REQUIRED TO FILL A CUBIC CENTIMETER CONTAINER TO THE BRIM FULL IS ONE GRAM.

40 SINCE A CUBIC CENTIMETER IS A SMALL VOLUME, A GRAM LIKEWISE IS ALSO A VERY SMALL UNIT OF VOLUME AS CAN BE SEEN BY THIS PICTURE.

41 THE SYMBOL FOR THE GRAM IS THE SMALL LETTERS "gr".

42 End (Music-fades in)

(Music-same level) (for 10 to 15 seconds)

(Music-fades completely out)

TEMPERATURE

Lesson #VI

Slide #	Script
-----	(Music-fades in) (for 10 to 15 seconds)
1	Start (Music-same level)
2	Focus (Music-same level)
3	Metric (Music-same level)
4	Temperature Lesson #VI
5	THIS LESSON IS ABOUT TEMPERATURE. WE SEE AND FEEL THE EFFECTS OF TEMPERATURE MANY TIMES DURING OUR DAILY LIVES. IT MAY BE THE HEAT OF A DAY IN SUMMER OR THE NEED TO TURN UP THE THERMOSTAT IN YOUR HOME ON A COLD WINTER DAY.
6	TEMPERATURE MUST BE SET ON THE OVEN BY YOUR MOTHER WHEN SHE BAKES A CAKE OR IT MAY BE NECESSARY TO CHECK THE TEMPERATURE OF YOUR FATHER WITH A THERMOMETER IF HE IS SICK.
7	FAHRENHEIT IS THE NAME OF THE SCALE ON THE CUSTOMARY THERMOMETER.
8	YOU PROBABLY ALREADY KNOW THAT 32° FAHRENHEIT IS THE FREEZING POINT OF WATER, 70° FAHRENHEIT IS A COMFORTABLE ROOM TEMPERATURE, 100° FAHRENHEIT IS THE TEMPERATURE ON A HOT SUMMER DAY AND 325° FAHRENHEIT IS ABOUT THE RIGHT TEMPERATURE FOR ROASTING A CHICKEN. BUT, THESE NUMBERS WILL ALL CHANGE WHEN WE BEGIN TO MEASURE TEMPERATURE USING SI UNITS.
9	PERHAPS YOU HAVE HEARD OF CENTIGRADE. THIS WAS THE ORIGINAL SCALE ON THE METRIC THERMOMETER. IT WAS DESIGNED SO THAT THE FREEZING AND BOILING POINTS OF WATER WOULD DIFFER BY 100 DEGREES. IT WAS CALLED CENTIGRADE BECAUSE CENTI MEANS ONE-HUNDREDTH AND EACH OF THE DEGREES WAS ONE-HUNDREDTH OR .01 OF THE TOTAL 100 DEGREES.

10 TODAY, THE CENTIGRADE SCALE HAS BEEN RENAMED TO CELSIUS AFTER THE MAN WHO INVENTED IT. CENTIGRADE HAS BECOME CELSIUS. ONLY THE NAME OF THE SCALE HAS BEEN CHANGED AS THE SCALE ITSELF REMAINS THE SAME.

11 THE CELSIUS SCALE IS BASED ON THE FREEZING AND BOILING POINTS OF WATER.

12 O DEGREES IS FREEZING, THE TEMPERATURE OF DISTILLED WATER TURNED TO ICE, AT SEA LEVEL BAROMETRIC PRESSURE,

13 WHILE 100 DEGREES IS BOILING, THE TEMPERATURE OF DISTILLED WATER TURNED TO STEAM, AT SEA LEVEL BAROMETRIC PRESSURE.

14 MOST WEATHER TEMPERATURES ARE BETWEEN 0 DEGREES AND 100 DEGREES, UNLESS THE TEMPERATURE FALLS BELOW FREEZING. BELOW FREEZING TEMPERATURES ARE MINUE (-) ON THE CELSIUS SCALE.

15 NORMAL BAKING AND ROASTING TEMPERATURES WOULD FALL ABOVE 100 DEGREES BECAUSE BAKING AND ROASTING ARE DONE ABOVE THE BOILING POINT OF WATER.

16 NORMAL BODY TEMPERATURE WILL BE APPROXIMATELY 37°C WHILE A COMFORTABLE ROOM TEMPERATURE WILL BE 25°C.

17 WHEN WRITING METRIC TEMPERATURES, DEGREES CELSIUS WILL BE ABBREVIATED BY THE SYMBOL ° FOLLOWED BY A CAPITAL C.

18 YES, TEMPERATURE AFFECTS US MANY TIMES A DAY AND WE OFTEN MEASURE IT. LETS TAKE JUST A FEW MOMENTS TO REVIEW. ALTHOUGH OUR WEATHER FORECASTS ARE CURRENTLY GIVEN IN DEGREES FAHRENHEIT, THEY WILL EVENTUALLY BE GIVEN IN DEGREES CELSIUS AS WE BEGIN TO SWITCH TO THE METRIC SYSTEM.

19 COOKING TEMPERATURES FOR RECIPES WILL ALSO BE GIVEN IN DEGREES CELSIUS.

20 THE TEMPERATURE OF A NICE SUNNY DAY WILL BE APPROXIMATELY 30 DEGREES CELSIUS,

21 WHILE NORMAL ROOM TEMPERATURES WILL BE APPROXIMATELY 25 DEGREES CELSIUS,

22 AND A HEALTHY CHILD OR ADULT WILL HAVE A NORMAL BODY TEMPERATURE OF APPROXIMATELY 37 DEGREES CELSIUS.

23 THE SCALE WHICH WE WILL USE TO MEASURE THESE TEMPERATURES IS CALLED A CELSIUS SCALE OR CELSIUS THERMOMETER.

24 THE CELSIUS THERMOMETER HAS A FREEZING POINT FOR WATER OF 0 DEGREES CELSIUS UNDER STANDARD CONDITIONS AND,

25 A BOILING POINT FOR WATER OF 100 DEGREES CELSIUS UNDER STANDARD CONDITIONS.

26 DEGREE CELSIUS IS SYMBOLIZED BY THE USE OF A CAPITAL LETTER "C" SINCE IT STANDS FOR THE NAME OF THE MAN WHO INVENTED IT AND THE "C" IS PRECEEDED BY THE DEGREE SIGN AND THE TEMPERATURE IS READ AS SO MANY DEGREES CELSIUS.

27 End (Music-fades in)

(Music-same level) (for 10 to 15 seconds)

(Music-fades completely out)

APPENDIX D

Instructional Approach A--Laboratory Activities

LINEAR
IN
SI MEASUREMENT

Lesson 3

LABORATORY ACTIVITIES

General Directions

Please do not write in this booklet. A special answer sheet, which will be supplied by your teacher, will be used to record your answers. You will need to supply your own soft lead pencil.

You will be asked to record the time that you start an activity (Time Started) and the time that you complete an activity (Time Completed). You will be asked to do this several times throughout this lesson. Please take special care to record these times on your answer sheet for each section of this lesson.

Lesson 3

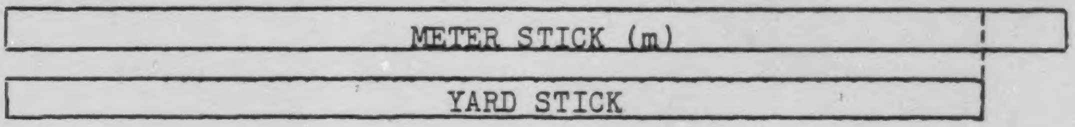
Linear Measurement Activities

SECTION #1

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

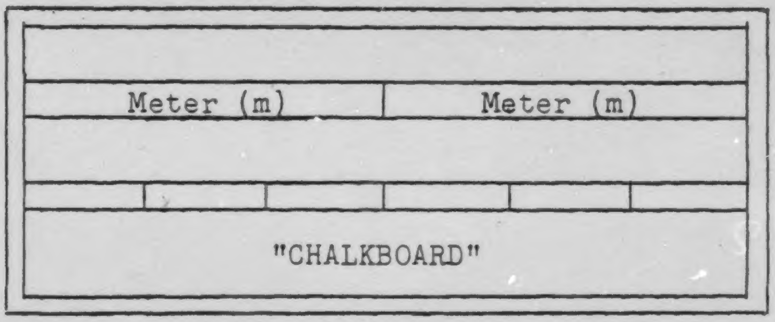
Meter

The meter is the basic unit of length in SI Measurement. The symbol for meter is the small letter "m". The meter is used to measure length. A meter stick is slightly longer than a yard stick.

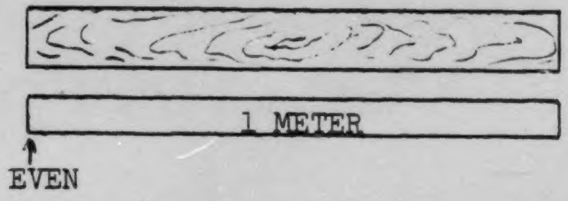


Take a good look at the length of one meter. Your teacher will hold a meter stick up for you to look at. The distance from one end of the meter stick to the other end is one meter.

The unit meter is frequently used when a person has to find the length of long objects. For example, to measure the length of a chalkboard it would be easier and faster to use a meter stick than a smaller measuring stick.



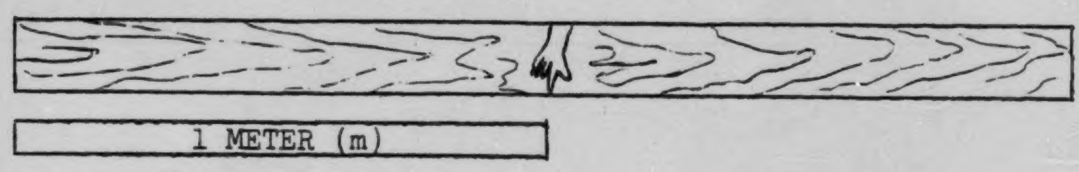
Now let's suppose that you are to measure the length of the piece of lumber shown below with a meter stick. Notice the way the meter stick is placed next to the board with the left end of the stick even with the left end of the piece of lumber.



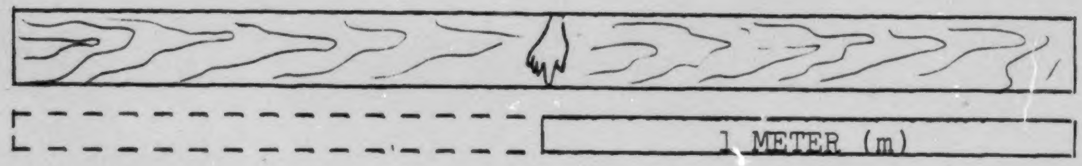
This piece of lumber measures one meter (1 m) long. This would be written on the answer sheet as ___1___ (number) ___m___. (SI symbol)

What is the best procedure to use when you have to measure a piece of lumber that is two or three meters long?

The first thing you do is to place the meter stick next to the piece of lumber and line up the end of the meter stick with the left end of the board.



Next, place your finger or a pencil mark on the board so that it is even with the right end of the meter stick. Move the meter stick along the board until the left end of the meter stick is at the spot on the board marked by your finger or the pencil line.



The piece of lumber on the preceding page measures exactly two meters (2 m) long. This would be recorded on the answer sheet as ___2___ ___m___.
(number) (SI symbol)

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

SECTION #2

Please look at the clock and record the correct time on your answer sheet beside the blank entitled, Time Started ________.

Laboratory Activities:

One student should go to each work station. Take your pencil, workbook and answer sheet with you.

Take the red meter stick from the kit. This meter stick measures exactly one meter (1 m) long.

1. Take the yellow plastic strip from your kit. How many meters long is the yellow strip? Measure it with the red meter stick. Write your number answer along with the proper SI symbol on the answer sheet beside item 1.

2. Take the white plastic strip from your kit. How many meters long is the white strip? Measure it with the red meter stick. Write your answer along with the proper SI symbol on the answer sheet beside item 2.

3. Take the blue plastic strip from your kit. How many meters long is the blue strip? Measure it with the red meter stick. Write your answer along with the proper SI symbol on the answer sheet beside item 3.

When you have completed this measurement exercise, place the three plastic strips and the red meter stick back into the kit.

Please look at the clock again and record the correct time on your _answer sheet_ beside the blank entitled, Time Completed ________.

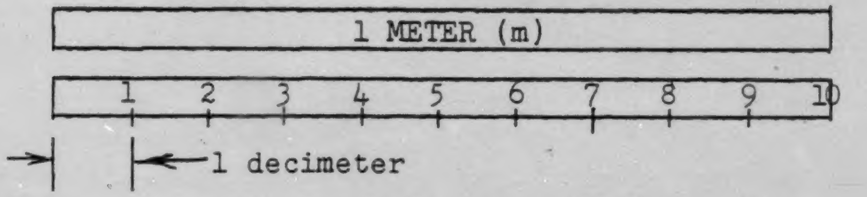
Return to your seat with your pencil, workbook and answer sheet.

SECTION #3

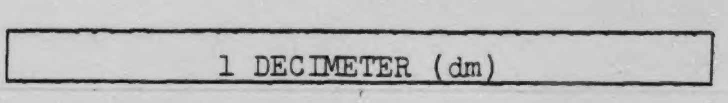
Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Decimeter

There are smaller SI measures than the meter which can be used to measure small objects. Since the SI System of Measurement is a decimal system (based on 10), smaller units are found by dividing the meter into 10 parts with each part being the same length, and then dividing each of those parts into 10 equal parts, and so on.



When the meter is divided into 10 equal parts, each of the 10 parts is called a decimeter. Your teacher will hold up a decimeter stick for you to look at. The symbol for decimeter is the small letters "dm". A decimeter is actually this long:



The decimeter is one-tenth or .1 meter. Some of you will find that it is about the width of your hand.

Key Points

1 m = 10 dm

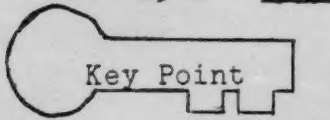
1 dm = .1 m

The decimeter is seldom used in measuring objects which are quite long. It does have an important use, though, and you will learn about that when you study volume/capacity.

PRACTICE PROBLEMS

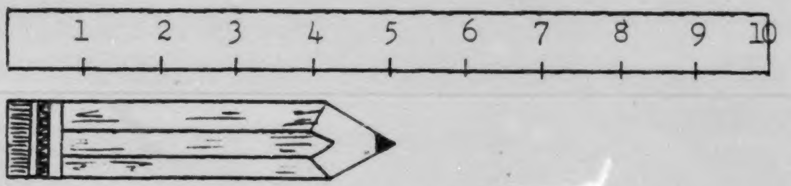
Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item numbers.

4. 5 m = _?_ dm
5. 10 m = _?_ dm
6. 13 m = _?_ dm
7. 30 dm = _?_ m
8. 70 dm = _?_ m
9. 140 dm = _?_ m



It is very important from now on that when you use a scale to measure something you place the end with the smallest number even with the end of the object you are measuring. A good example would be to measure the length of a pencil as indicated below. Notice that the end of the scale (small numbered end) is even with the end of the pencil.

SMALL
NUMBERED
END



Pencil and scale are even

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

SECTION #4

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Laboratory Activities:

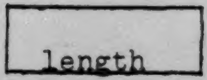
One student should go to each work station. Take your pencil, workbook and answer sheet with you.

Take the following items from your kit:

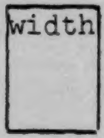
--Blue rectangle "A".

--Wood decimeter stick which is 10 dm long.

10. Measure the length (longest side) of the blue rectangle with the decimeter stick. Write your answer in decimeters and the proper SI symbol on the answer sheet beside item 10.



11. Measure the width of the blue rectangle with the decimeter stick. Write your answer in decimeters along with the proper SI symbol on the answer sheet beside item 11.



When you have completed this measurement exercise, return the blue rectangle "A" and decimeter stick to the kit.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

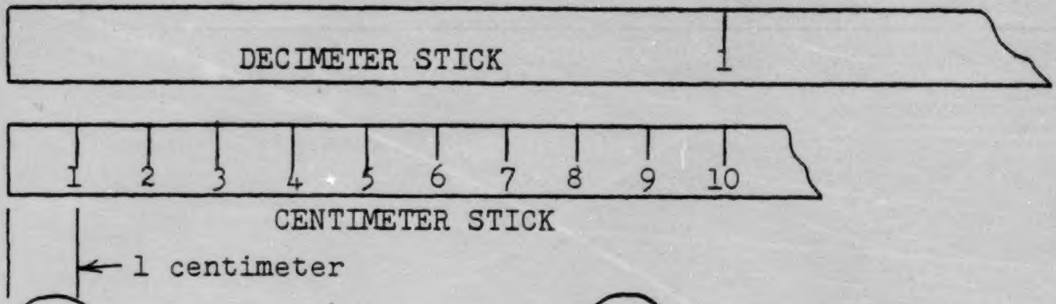
Return to your seat with the pencil, workbook and answer sheet.

SECTION #5

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Centimeter

When the decimeter is divided into 100 equal parts, each of the 10 small parts is equal to one centimeter. Your teacher will hold up a short orange scale which is divided into centimeters. Use the small letters "cm" as a symbol which stands for the word centimeter.



Key Point

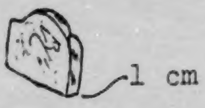
1 dm = 10 cm

"Centi" means "hundredth." The centimeter is an SI measure of length that is equal to one-hundredth or .01 meter.

Key Point

1 m = 10 dm = 100 cm

The thickness of one slide of sandwich bread is approximately equal to 1 cm or 1 centimeter.



At the present time you will probably use the centimeter unit more than any other SI unit we have talked about.

PRACTICE PROBLEMS

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item numbers.

12. 1 dm = __?__ cm
13. __?__ cm = 5 dm
14. __?__ cm = 10 dm
15. __?__ m = 300 cm
16. __?__ cm = 2 m
17. 400 cm = __?__ m

Key Point Remember that when you are using a scale you should place the end with the smallest number even with the left end of the object which you are measuring.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled,

Time Completed ________.

SECTION #6

Please look at the clock and record the correct time on your answer sheet beside the blank entitled, Time Started ________.

Laboratory Activities:

One student should go to each work station. Take your pencil, workbook and answer sheet with you.

Take the following items from your kit:

--Green triangle marked A, B, C.

--Orange centimeter stick.

--Paper clip.

--Bolt-Metal.

18. Do not use a scale for this problem. Estimate the length of side A of the green triangle, in centimeters. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number in the ESTIMATE column.

19. Do not use a scale for this problem. Estimate the length of side B of the green triangle, in centimeters. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number in the ESTIMATE column.

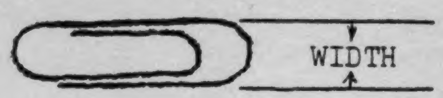
20. Do not use a scale for this problem. Estimate the length of side C of the green triangle, in centimeters. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number in the ESTIMATE column.

21. Measure the length of side A of the green triangle with the orange centimeter stick. Write your answer along with the proper SI symbol on the answer sheet in the MEASUREMENT column.

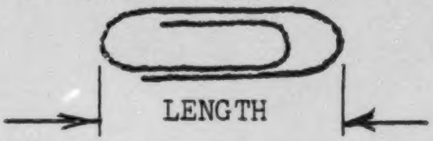
22. Measure the length of side B of the green triangle with the orange centimeter stick. Write your answer along with the proper SI symbol on the answer sheet in the MEASUREMENT column.

23. Measure the length of side C of the green triangle with the orange centimeter stick. Write your answer along with the proper SI symbol on the answer sheet in the MEASUREMENT column.

24. Measure the width of the paper clip with the orange centimeter stick. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



25. Measure the length of the paper clip with the orange centimeter stick. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



26. Measure the length of the metal bolt with the centimeter stick. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.

27. Draw a line that is 9 cm long on your answer sheet beside the corresponding item number, using the centimeter stick. Begin this measurement at the star on your answer sheet beside the corresponding item number.

28. Start at the zero ("0") on the answer sheet and draw a line that is 5 cm long. Use your centimeter stick for this measurement.

When you have completed this measurement exercise, return the centimeter stick (orange), the green triangle, the paper clip, and the metal bolt to the kit.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Return to your seat with your pencil, workbook, and answer sheet.

SECTION #7

Please look at the clock and record the correct time on your answer sheet beside the blank entitled, Time Started ________.

Kilometer

Just as there are smaller SI units such as the centimeter, there are also larger SI units used for measuring length. The unit most often used to measure long distances is the kilometer. The kilometer is a unit of length equal to 1 000 meters. "Kilo" means "one thousand." The symbol for kilometer is the small letters "km".

Key Point 1 km = 1 000 m

The kilometer is about the same distance as going around a baseball diamond 9¼ times. The distance from McDonald's to Reese Elementary School is 1½ kilometers; to Ridgeview Elementary School is 3½ kilometers; and to Southeast Elementary School is 2¼ kilometers.

PRACTICE PROBLEMS

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item numbers.

29. 2 km = __?__ m
30. 32 km = __?__ m
31. 8 km = __?__ m
32. 4 000 m = __?__ km
33. 16 000 m = __?__ km
34. 9 000 m = __?__ km

Several problems related to distance are given below. You are to find the correct distance by using the map which is provided. Please record the distance in kilometers and the other information requested on the separate answer sheet.

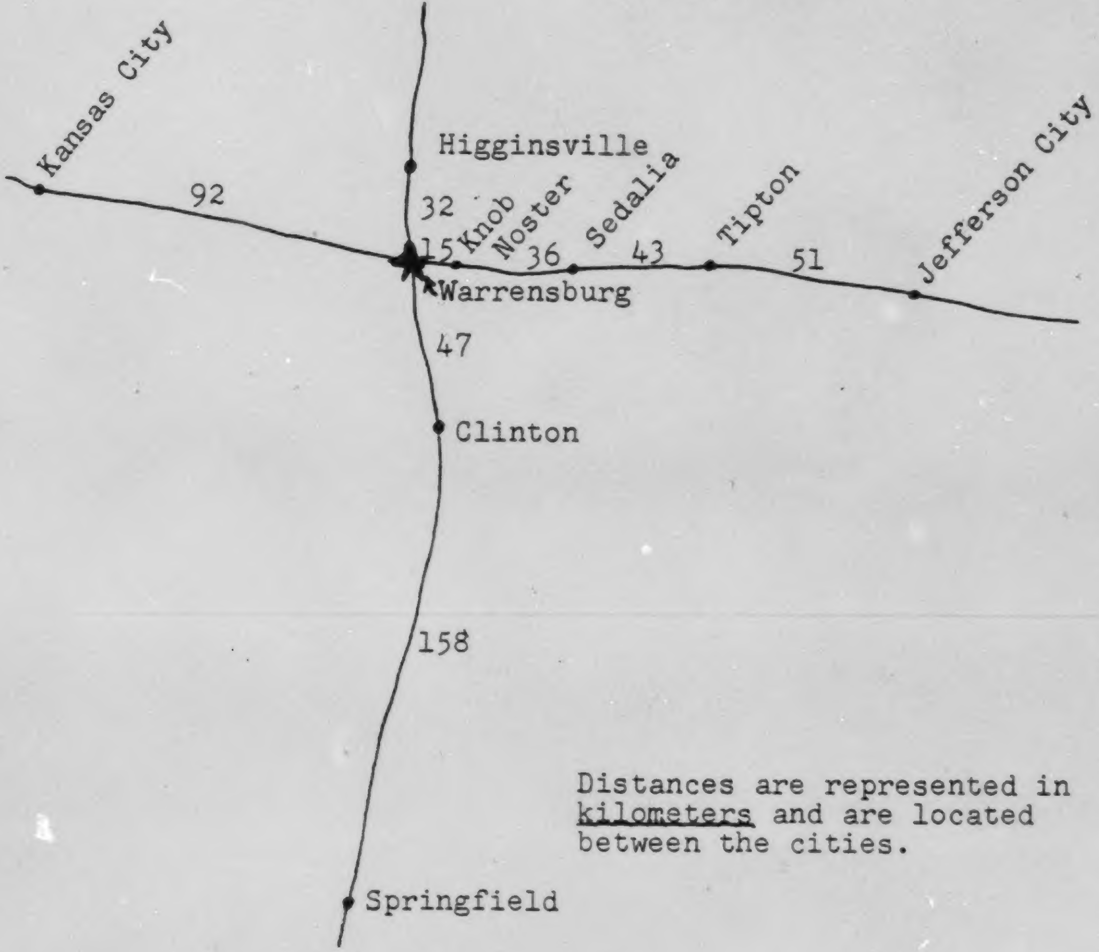
35. Warrensburg to Higginsville

36. Warrensburg to Sedalia

37. Warrensburg to Jefferson City

38. Is Warrensburg closer to Springfield or to Jefferson City?

39. Is Warrensburg closer to Kansas City or to Tipton?


Kansas City
92
Higginsville
32
15
Knob Noster
36
Sedalia
43
Tipton
51
Jefferson City
Warrensburg
47
Clinton
158
Springfield

Distances are represented in kilometers and are located between the cities.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Check all your answers with the KEY. You will find that the answers are not supplied for the Estimate questions. There are no wrong answers for the Estimate questions. However, notice the difference, if any, between your Estimated Measurement answers and the actual Measurement answers. This will help to show how well you understand SI Measurement.

Answer Sheet for

Lesson 3--Laboratory Activity

Student # ____________ Teacher # ____________

SECTION #1--Time Started ____________

Time Completed ____________

SECTION #2--Time Started ____________

1. Yellow strip ________ ________
(number) (SI symbol)

2. White strip ________ ________
(number) (SI symbol)

3. Blue strip ________ ________
(number) (SI symbol)

Time Completed ____________

SECTION #3--Time Started ____________

4. 5 m = ________ dm
(number)

5. 10 m = ________ dm
(number)

6. 13 m = ________ dm
(number)

7. 30 dm = ________ m
(number)

(Section #3 Continued Next Page)

8. 70 dm = ________ m
(number)

9. 140 dm = ________ m
(number)

Time Completed ______________

SECTION #4--Time Started ______________

10. Length ________ ________
(number) (SI symbol)

11. Width ________ ________
(number) (SI symbol)

Time Completed ______________

SECTION #5--Time Started ______________

12. 1 dm = ________ cm
(number)

13. ________ cm = 5 dm
(number)

14. ________ cm = 10 dm
(number)

15. ________ m = 300 cm
(number)

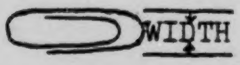
16. ________ cm = 2 m
(number)

17. 400 cm = ________ m
(number)

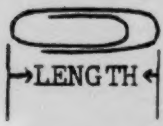
Time Completed ______________

SECTION #6--Time Started ________________

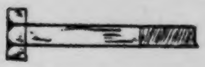
ESTIMATE		MEASUREMENT
18. ______ ______ (number)(SI symbol)	←Compare→ Side A	21. ______ ______ (number)(SI symbol)
19. ______ ______ (number)(SI symbol)	←Compare→ Side B	22. ______ ______ (number)(SI symbol)
20. ______ ______ (number)(SI symbol)	←Compare→ Side C	23. ______ ______ (number)(SI symbol)

24. 

______ ______
(number) (SI symbol)

25. 

______ ______
(number) (SI symbol)

26. 
______ ______
(number) (SI symbol)

27. ★

28. "O"

Time Completed ________________

SECTION #7--Time Started ________________

29. 2 km = ________ m
(number)

30. 32 km = ________ m
(number)

(Section #7 Continued Next Page)

31. 8 km = ________ m
(number)

32. 4 000 m = ________ km
(number)

33. 16 000 m = ________ km
(number)

34. 9 000 m = ________ km
(number)

35. Warrensburg to Higginsville ________ ________
(number) (SI symbol)

36. Warrensburg to Sedalia ________ ________
(number) (SI symbol)

37. Warrensburg to Jeff City ________ ________
(number) (SI symbol)

38. Warrensburg is closest to ____________, which
(name of city)
is a distance of ________ ________.
(number) (SI symbol)

39. The distance from Warrensburg to Kansas City is
________ ________ and the distance from
(number) (SI symbol)
Warrensburg to Tipton is ________ ________.
(number) (SI symbol)
Therefore, Warrensburg is closer to
____________ by a distance of ________
(name of city) (number)
________.
(SI symbol)

Time Completed ______________

VOLUME/CAPACITY
IN
SI MEASUREMENT

Lesson 4

LABORATORY ACTIVITIES

General Directions

Please do not write in this booklet. A special answer sheet, which will be supplied by your teacher, will be used to record your answers. You will need to supply your own soft lead pencil.

You will be asked to record the time when you start an activity (Time Started) and the time when you complete an activity (Time Completed). You will be asked to do this several times throughout this lesson. Please take special care to record these times on your answer sheet for each section of this lesson.

Lesson 4

Volume/Capacity Measurement Activities

SECTION #1

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Volume or capacity is the amount of a substance or material that is held in or contained by a container. In other words, volume or capacity is the space inside a hollow object as well as the space which a solid object takes up. The volume or capacity of a container is measured in cubic units and the material to be measured may be a wet or liquid substance or it may also be a dry or solid material.

A cube is an object which has sides of equal length. In other words, a cube is a container where length = width = height. Here we have drawn a picture of a block or container that is a cube. This block or container has a volume or capacity of one cubic unit as shown in Figure #1.

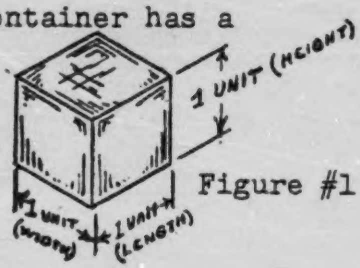


Figure #1

How many cubic units are needed to build the figure below in Figure #2?

There are two rows of blocks with 3 blocks in each row. We can therefore say that there are 2 x 3 or 6 cubic units in the figure.

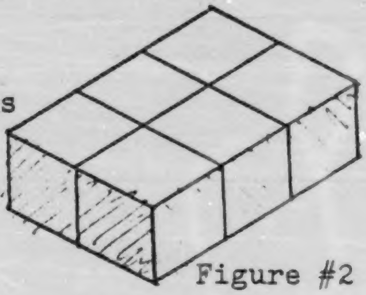
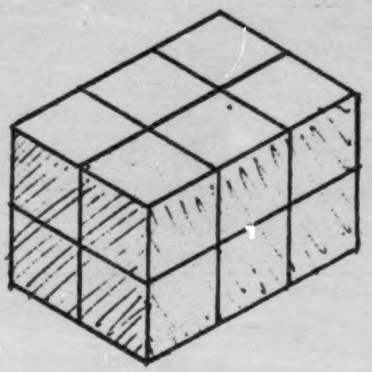


Figure #2

Now let's lay another layer of cubes on the top of the figure which we just examined. How many cubic units are needed for this new figure?

We again have two rows of blocks with three blocks in each row, which makes a total of 2 x 3 or 6 cubic units for the first layer. However, since there are two layers with 6 cubic units in each layer, we now have a volume of 12 cubic units (6 units x 2 layers) in the new figure which appears to the right.



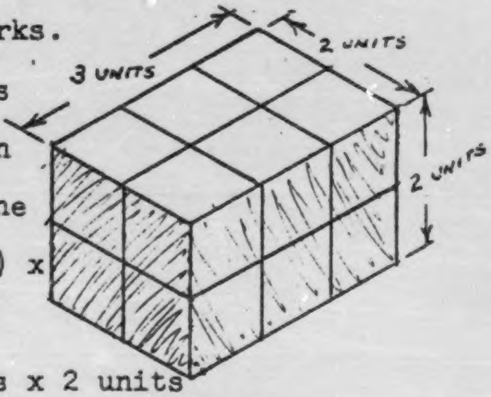
There is still a simpler way to figure the volume of an object. You can find the volume of something by using the following formula:

Volume = length x width x height
(This can be abbreviated as follows)

V = L x W x H

Let's use the same problem which we just studied to see how the formula for volume works.

To find the volume of this figure, use the formula above. In other words, volume is equal to the length (3 units) x width (2 units) x height (2 units).



Volume = 3 units x 2 units x 2 units

or Volume = 12 cubic units.

Therefore the volume or capacity of the figure on the preceding page would have been written 12 units^3 (read "cubic units"). The small "3" which is placed above and to the right of the word "unit" is used to show that a volume measure has been made. In other words, when we multiply the length x width x height of an object we get the volume or capacity of the object which is given in units cubed. This is written "units^3".

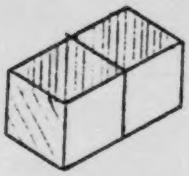
PRACTICE PROBLEMS:

Please figure the volume or capacity of each of the objects shown below. Write your answer on the answer sheet beside the corresponding item number.

Formula for Volume

Volume = length x width x height

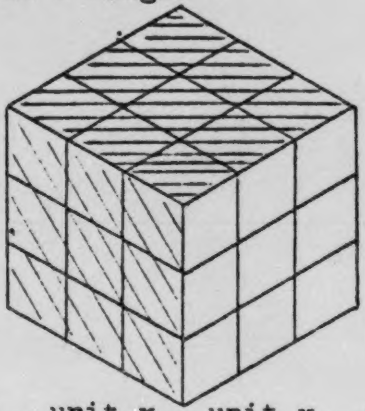
1.



V = __unit x __unit x __unit

V = __________units^3

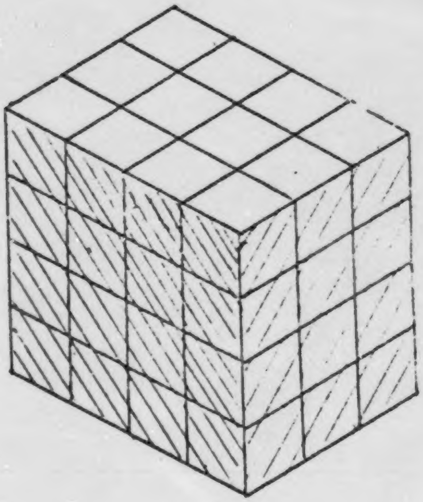
2.



V = __unit x __unit x __unit

V = __________units^3

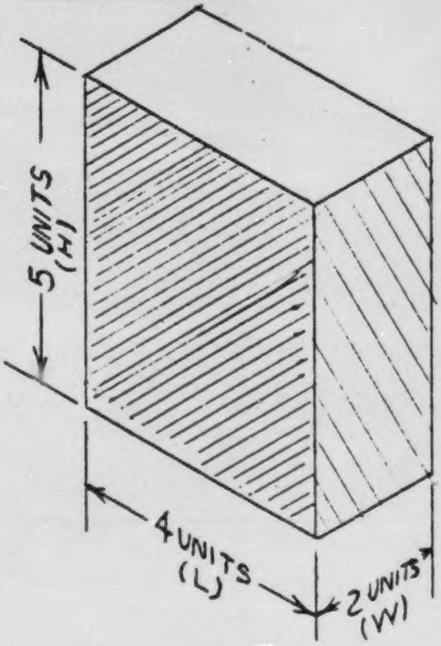
3.



V = __unit x __unit x __unit

V = __________units^3

4.

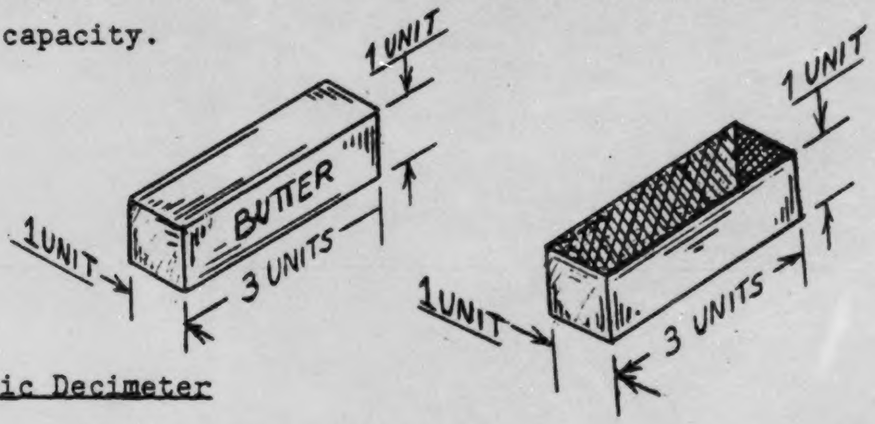


V = __unit x __unit x __unit

V = __________units^3

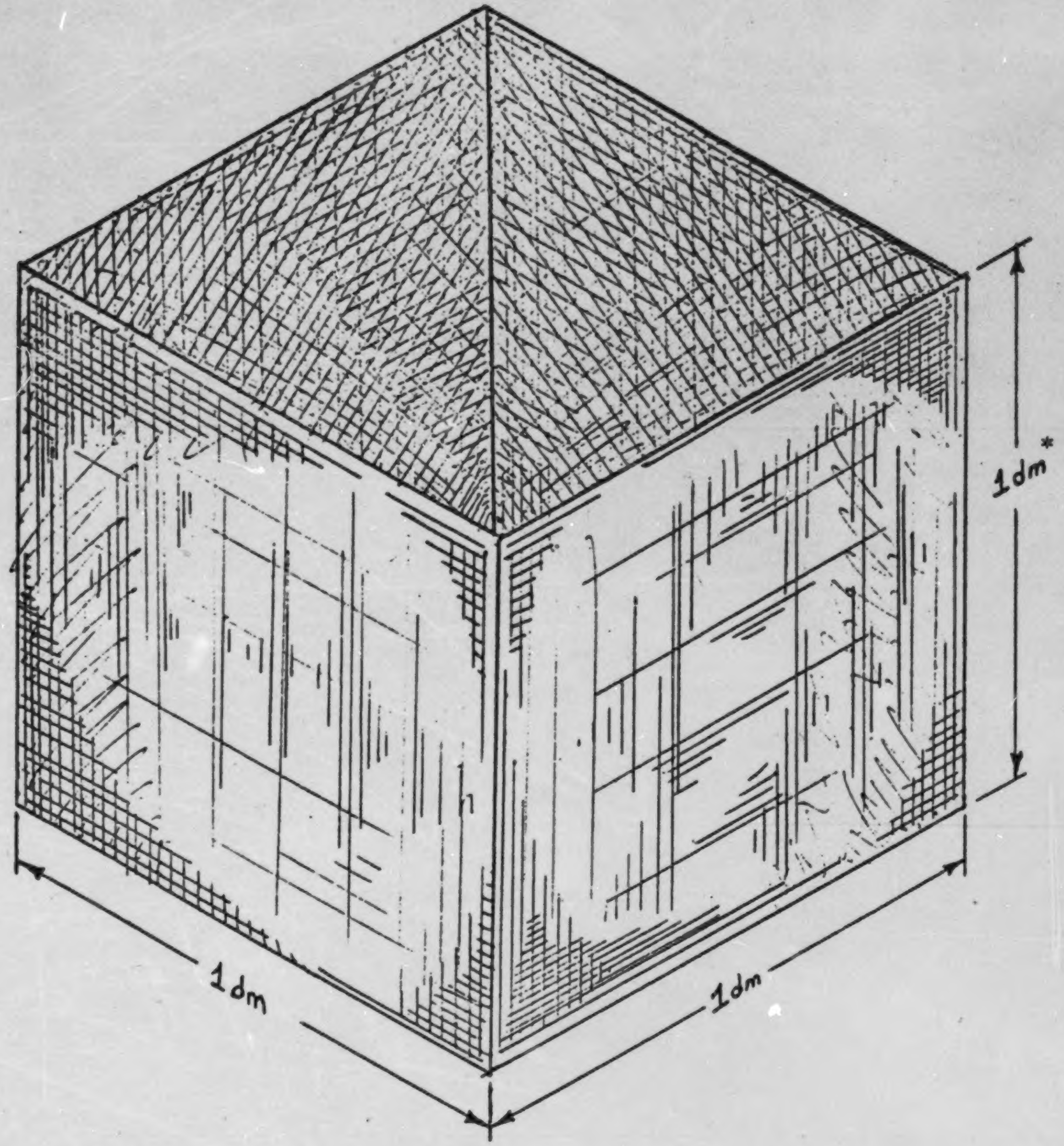
Key Point The volume or capacity of solid objects as well as empty boxes or containers is figured in cubic units.

The examples below show that a piece of butter and an empty box with the same dimensions have the same volume or capacity.



Cubic Decimeter

We have been studying about volume or capacity of objects which are measured in cubic units. One of the SI units which is used to measure volume or capacity is the cubic decimeter. The SI symbol for the cubic decimeter is "dm^3". It is a cube where the length of each side is 1 decimeter (dm). We can therefore say that it has a capacity or volume of 1 dm^3. The figure on the next page represents a true volume of one cubic decimeter (dm^3).



*This page is reduced 23% from the original.

Your teacher will hold up a cube that also has a volume of one cubic decimeter (dm^3). A cubic decimeter is about the same size as the bottom half of a half-gallon milk carton and therefore has the same volume or capacity.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

SECTION #2

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Laboratory Activities:

One student should go to each work station. Take your pencil, workbook, and answer sheet with you.

5. Do not use measuring instruments for this question. Remove the half-gallon milk carton labeled "B" from the kit. Estimate the volume, in cubic decimeters (dm^3), of the milk carton ($V = L \times W \times H$). Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place carton "B" to one side as you will be using it again.

6. Do not use measuring instruments for this question. Remove the foam rubber block labeled "C" from the kit. Estimate the volume, in cubic decimeters (dm^3), of the foam rubber block ($V = L \times W \times H$). Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place block "C" to one side as you will be using it again.

7. Do not use measuring instruments for this question. Estimate the volume, in cubic decimeters (dm^3), of the box at your work station in which everything is stored (V = L x W x H). Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

Remove the wood decimeter stick which is 10 dm long from your kit.

8. Find the volume or capacity, to the nearest cubic decimeter (dm^3), of the milk carton labeled "B" by measuring the sides of the carton with the wood decimeter stick. Use the formula V = L x W x H to figure the volume. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

9. Find the volume or capacity, in cubic decimeters (dm^3), of the foam rubber block labeled "C" by measuring the block with the decimeter stick. Use the formula V = L x W x H to figure the volume. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

10. Find the volume or capacity, to the nearest cubic decimeter (dm^3), of the box at your work station in which everything is stored. Measure the box with the decimeter stick. Use the formula V = L x W x H to figure the volume. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

When you have completed this exercise, return the decimeter stick, the milk carton "B", and the foam rubber block "C" to the kit.

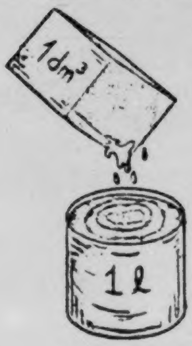
Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed __________.

SECTION #3

Please look at the clock and record the correct time on the answer sheet. Do this at this time on the blank entitled, Time Started ________.

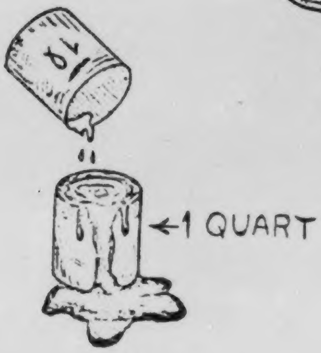
Liter

Earlier in this lesson it was mentioned that the volume or capacity of a liquid can also be measured. Thus far we have only discussed cubic units and in particular the cubic decimeter which was used to measure the volume or capacity of solid objects and empty containers. It so happens that there is a relationship between the cubic units which we have discussed and liquid units. For example, the volume or capacity of 1 cubic decimeter is 1 liter. The liter is the basic unit of capacity. The symbol for liter is the small letter "l". The small letter "l" is also made in the cursive form which is "ℓ" so that it will not be confused with the number 1.



Key Point $1\ell = 1\ \mathrm{dm}^3$

One liter is slightly more than a quart.



In SI Measurement, we measure liquid substances such as milk and gas by the liter (ℓ). Liquids are measured with the aid of graduates, beakers, cylinders, etc. Your teacher will show you an example of a liter measure at a later time during this lesson.

PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item number.

11. $1\ dm^3 = \underset{\text{(number)}}{\underline{\quad ? \quad}}\ \ell$

12. $3\ dm^3 = \underset{\text{(number)}}{\underline{\quad ? \quad}}\ \ell$

13. $\underset{\text{(number)}}{\underline{\quad ? \quad}}\ dm^3 = 15\ \ell$

14. $\underset{\text{(number)}}{\underline{\quad ? \quad}}\ dm^3 = 9\ \ell$

15. $7\ dm^3 = \underset{\text{(number)}}{\underline{\quad ? \quad}}\ \underset{\text{(SI symbol)}}{\underline{\quad ? \quad}}$

16. $\underset{\text{(number)}}{\underline{\quad ? \quad}}\ \underset{\text{(SI symbol)}}{\underline{\quad ? \quad}} = 12\ \ell$

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

SECTION #4

Please look at the clock and record the correct time on the answer sheet. Do this at this time on the blank entitled, Time Started ________.

Laboratory Activities:

One student should go to each work station. Take your workbook, answer sheet and pencil with you. Remove the containers labeled "D" (coffee can) and "B" (milk carton with top removed) from the kit.

17. Do not use measuring instruments for this question. Estimate the liter (ℓ) capacity of container "D" (coffee can). Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

18. Do not use measuring instruments for this question. Estimate the liter (ℓ) capacity of container "B" (milk carton with top removed). Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

Remove the following items from your kit:

--Plastic liter measure

--Large container filled with sand

--Plastic funnel

NOTE: In the activities that follow we would like for you to pretend that the sand which you will be using is water. It was felt that water would create more of a mess than would sand.

19. Measure the liter (ℓ) capacity of container "D" (coffee can) using the following steps. First fill container "D" with sand and then pour the sand into the plastic liter measure. Write your answer along with the proper SI symbol on the answer sheet. Pour the sand from the liter measure into container "B" (milk carton). Do this as rapidly as you can. Continue on with problem 20.

20. Measure the liter (ℓ) capacity of container "B" (milk carton with top removed) by using the following steps. First fill the remainder of container "B" with sand and then pour the sand into the liter measure. To measure the capacity of this container you may find it necessary to empty and fill the liter measure more than once. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Pour the sand from the liter measure back into the large sand container with the aid of the funnel. Do this as rapidly as you can.

Return containers "D" and "B", the large sand container, the funnel, and the liter measure to the kit.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

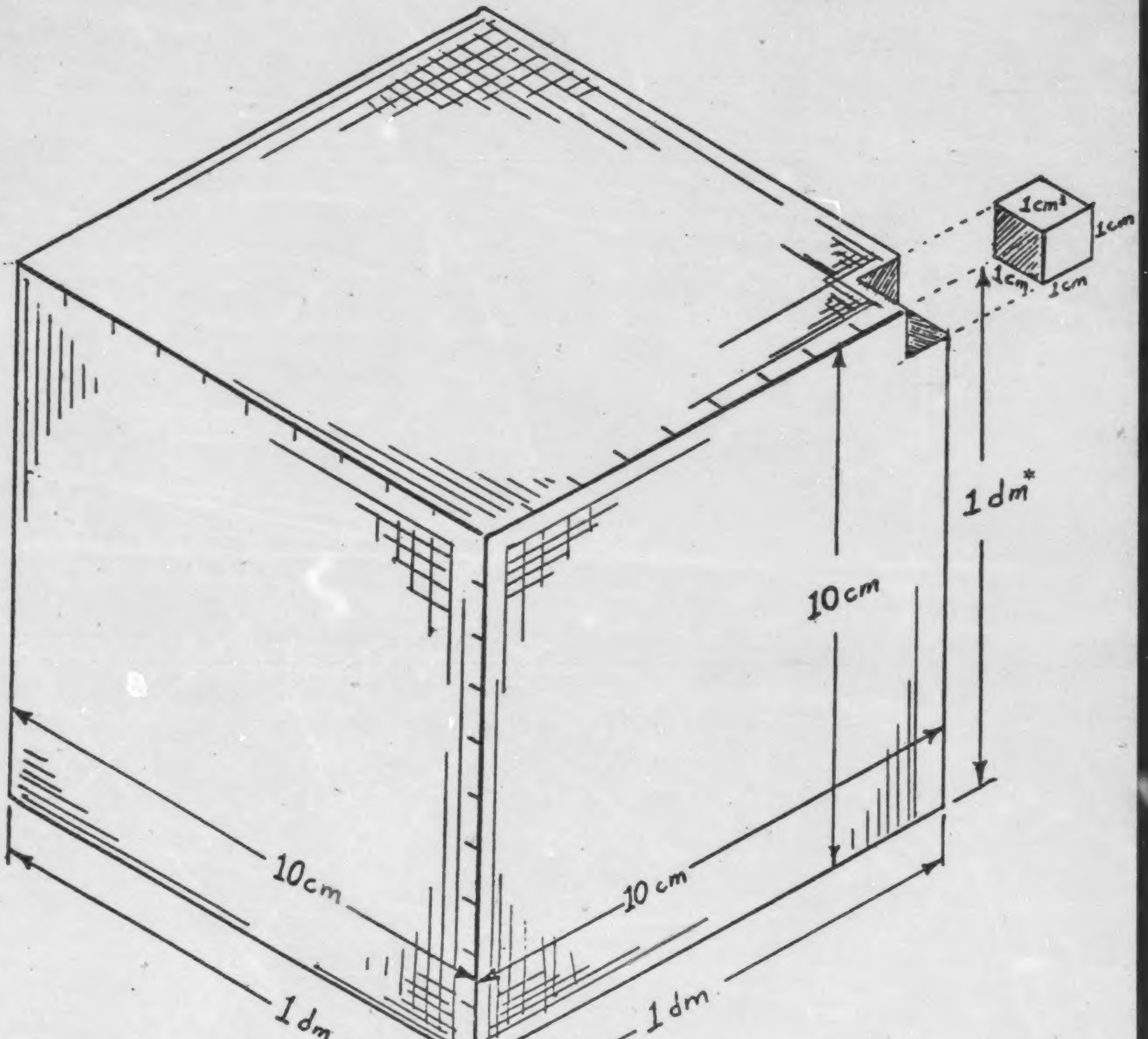
Return to your desk with pencil, workbook, and answer sheet.

SECTION #5

Please look at the clock and record the correct time on the answer sheet. Do this at this time on the blank entitled, Time Started ________.

Cubic Centimeter

A cubic centimeter is a unit of volume that is used to make smaller measures. The symbol for cubic centimeter may be written as (cm^3). Notice in the figure on the following page the actual size of a cubic centimeter (cm^3) and its relationship to the cubic decimeter.


1cm³
1cm
1cm
1cm
1 dm*
10cm
10cm
10 cm
1 dm
1 dm

*This page is reduced 38.5% from the original.

A sugar cube is a little larger in size than a cubic centimeter.

Do you know how many cubic centimeters there are in a cubic decimeter? Let's review and find out.

Key Point Remember that the volume can be found by using the formula: Volume = Length x Width x Height, which is abbreviated V = L x W x H.

Therefore, if we substitute the number of centimeters that are in a decimeter (10 centimeters = 1 decimeter) for each of the three dimensions, we find that:

Volume of 1 dm^3 = 10 cm x 10 cm x 10 cm

(therefore)

Volume of 1 dm^3 = 1 000 cm^3

Key Point 1 dm^3 = 1 000 cm^3 1 cm^3 = .001 dm^3

From the above problem we can see that it would take approximately 1,000 sugar cubes to fill the cubic decimeter container shown on the preceding page.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

SECTION #6

Please look at the clock and record the correct time on the answer sheet. Do this at this time on the blank entitled, Time Started ________.

Laboratory Activities:

One student should go to each work station. Take your workbook, answer sheet and pencil with you. Remove the boxes labeled "F", "G", "H" and "I" from the kit.

21. Do not use measuring instruments for this question. Estimate the volume, in cubic centimeters (cm^3), of box "F". (V = L x W x H) Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place box "F" to one side as you will be using it again.

22. Do not use measuring instruments for this question. Estimate the volume, in cubic centimeters (cm^3), of box "G". (V = L x W x H) Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place box "G" to one side as you will be using it again.

23. Do not use measuring instruments for this question. Estimate the volume, in cubic centimeters (cm^3), of box "H". ($V = L \times W \times H$) Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place box "H" to one side as you will be using it again.

24. Do not use measuring instruments for this question. Estimate the volume, in cubic centimeters (cm^3), of box "I". ($V = L \times W \times H$) Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place box "I" to one side as you will be using it again.

Remove the orange centimeter stick from the kit.

25. Measure the volume, in cubic centimeters (cm^3), of box "F" by measuring it with the centimeter stick. Use the formula $V = L \times W \times H$ to find the volume. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

26. Measure the volume, in cubic centimeters (cm^3), of box "G" by measuring it with the centimeter stick. Use the formula $V = L \times W \times H$ to find the volume. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

27. Measure the volume, in cubic centimeters (cm^3), of box "H" by measuring it with the centimeter stick. Use the formula $V = L \times W \times H$ to find the volume. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

28. Measure the volume, in cubic centimeters (cm^3), of box "I" by measuring it with the centimeter stick. Use the formula $V = L \times W \times H$ to find the volume. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

When you are finished, return boxes "F", "G", "H", and "I" along with the orange centimeter stick to the kit.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Return to your desk with pencil, workbook and answer sheet.

SECTION #7

Please look at the clock and record the correct time on the answer sheet. Do this at this time on the blank entitled, Time Started ________.

Milliliter

It was mentioned earlier that the capacity of one cubic decimeter (1 dm^3) is equal to one liter (1 ℓ). The same relationship exists between the cubic centimeter and the milliliter. The prefix milli is used to represent one-thousandth of something. The capacity of one cubic centimeter (1 cm^3) is equal to one milliliter (1 mℓ). The symbol for milliliter is the small letters "mℓ".

Key Point $1\ cm^3 = 1\ m\ell$

This relationship is best explained by recalling a few key points:

1. You will recall that the prefix milli is used to represent one-thousandth. Therefore we can assume that a milliliter (mℓ) is 1 of 1 000 parts of a liter.

Key Point milli = one thousandth

2. You were also told that each cubic centimeter is 1 of 1 000 parts of a cubic decimeter.

Key Point $1\ dm^3 = 1\ 000\ cm^3$

3. Therefore, since you were told that one cubic decimeter (1 dm^3) has a capacity of one liter (1 ℓ), then one cubic centimeter has a capacity of one milliliter (1 mℓ).

Key Point 1 dm^3 = 1 ℓ and 1 cm^3 = 1 mℓ

A thimble will hold about one milliliter (mℓ) of water, while a teaspoon will hold about 5 milliliters (mℓ) of water.

Very small amounts of liquids like medicines are measured in milliliters (mℓ). Your teacher will show you a graduate which can be used to very accurately measure small amounts of liquids.

PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write the answer for each question on the answer sheet beside the corresponding item number.

29. 1 mℓ = ? (number) cm^3

30. 2 000 cm^3 = ? (number) ℓ

31. 5 000 mℓ = ? (number) ℓ

32. 2 000 cm^3 = ? (number) dm^3

33. ? (number) mℓ = 9 ℓ

34. 18 000 cm^3 = ? (number) ℓ

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

SECTION #8

Please look at the clock and record the correct time on the answer sheet. Do this at this time on the blank entitled, Time Started ________.

Laboratory Activities:

One student should go to each work station. Take your workbook, answer sheet and pencil with you. Remove the containers labeled "J", "K", "L" and "M" from the kit.

35. Do not use measuring instruments for this question. Estimate the capacity, in milliliters (mℓ) of container "J". Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place container "J" to one side as you will be using it again.

36. Do not use measuring instruments for this question. Estimate the capacity, in milliliters (mℓ) of container "K". Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place container "K" to one side as you will be using it again.

37. Do not use measuring instruments for this question. Estimate the capacity, in milliliters ($m\ell$) of container "L". Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place container "L" to one side as you will be using it again.

38. Do not use measuring instruments for this question. Estimate the capacity, in milliliters ($m\ell$) of container "M". Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Place container "M" to one side as you will be using it again.

Remove the following items from your kit:

--100 $m\ell$ plastic graduate

--250 $m\ell$ glass graduate

--Large container filled with sand

39. Measure the capacity of container "J" by using the following steps. First fill container "J" with sand and then pour the sand into the 100 milliliter graduate. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. Then pour the sand from the 100 milliliter graduate back into the large sand container with the aid of a funnel.

41. Measure the capacity of container "L" by using the following steps. First fill container "L" with sand and then pour the sand into the 250 milliliter graduate. Write your answer along with the SI symbol on the answer sheet beside the corresponding item number. Then pour the sand from the 250 milliliter graduate back into the large sand container with the aid of a funnel.

42. Measure the capacity of container "M" by using the following steps. First fill container "M" with sand and then pour the sand into the 250 milliliter graduate. Write your answer along with the SI symbol on the answer sheet beside the corresponding item number. Then pour the sand from the 250 milliliter graduate back into the large sand container with the aid of a funnel.

When you are finished, return containers "J", "K", "L", and "M", the container of sand, and the graduates back into the kit.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Return to your desk with pencil, workbook, and answer sheet.

Check all of your answers with the KEY. You will find that the answers are not supplied for the Estimate questions. There are no wrong answers for the Estimate questions. However, notice the difference, if any, between your Estimated measurement answers and the actual Measurement answers.

Answer Sheet for

Lesson 4--Laboratory Activity

Student # ____________________ Teacher # ____________________

SECTION #1--Time Started ________________

1. V = ________ units^3
   (number)

2. V = ________ units^3
   (number)

3. V = ________ units^3
   (number)

4. V = ________ units^3
   (number)

Time Completed ________________

SECTION #2--Time Started ________________

ESTIMATE		MEASUREMENT
5. ______ ________ (number)(SI symbol)	←Compare→	8. ______ ________ (number)(SI symbol)
6. ______ ________ (number)(SI symbol)	←Compare→	9. ______ ________ (number)(SI symbol)
7. ______ ________ (number)(SI symbol)	←Compare→	10. ______ ________ (number)(SI symbol)

Time Completed ________________

SECTION #3--Time Started ______________

11. 1 dm^3 = ______ (number) ℓ

12. 3 dm^3 = ______ (number) ℓ

13. ______ (number) dm^3 = 15 ℓ

14. ______ (number) dm^3 = 9 ℓ

15. 7 dm^3 = ______ (number) ______ (SI symbol)

16. ______ (number) ______ (SI symbol) = 12 ℓ

Time Completed ______________

SECTION #4--Time Started ______________

	ESTIMATE			MEASUREMENT
17.	______ (number) ______ (SI symbol)	←Compare→	19.	______ (number) ______ (SI symbol)
18.	______ (number) ______ (SI symbol)	←Compare→	20.	______ (number) ______ (SI symbol)

Time Completed ______________

SECTION #5--Time Started ______________

Time Completed ______________

SECTION #6--Time Started ________________

ESTIMATE **MEASUREMENT**

21. ______ ________ ←Compare→ 25. ______ ________
(number)(SI symbol) (number)(SI symbol)

22. ______ ________ ←Compare→ 26. ______ ________
(number)(SI symbol) (number)(SI symbol)

23. ______ ________ ←Compare→ 27. ______ ________
(number)(SI symbol) (number)(SI symbol)

24. ______ ________ ←Compare→ 28. ______ ________
(number)(SI symbol) (number)(SI symbol)

Time Completed ________________

SECTION #7--Time Started ________________

29. 1 mℓ = ________ cm^3
(number)

30. 2 000 cm^3 = ________ ℓ
(number)

31. 5 000 mℓ = ________ ℓ
(number)

32. 2 000 cm^3 = ________ dm^3
(number)

33. ________ mℓ = 9 ℓ
(number)

34. 18 000 cm^3 = ________ ℓ

Time Completed ________________

SECTION #8--Time Started ______________

ESTIMATE **MEASUREMENT**

35. ________ ____________ ←Compare→ 39. ________ ____________
(number)(SI symbol) (number)(SI symbol)

36. ________ ____________ ←Compare→ 40. ________ ____________
(number)(SI symbol) (number)(SI symbol)

37. ________ ____________ ←Compare→ 41. ________ ____________
(number)(SI symbol) (number)(SI symbol)

38. ________ ____________ ←Compare→ 42. ________ ____________
(number)(SI symbol) (number)(SI symbol)

Time Completed ______________

MASS/WEIGHT
IN
SI MEASUREMENT

Lesson 5

LABORATORY ACTIVITIES

General Directions

Please do not write in this booklet. A special answer sheet, which will be supplied by your teacher, will be used to record your answers. You will need to supply your own soft lead pencil.

You will be asked to record the time when you start an activity (Time Started) and the time when you complete an activity (Time Completed). You will be asked to do this several times throughout this lesson. Please take special care to record these times on your answer sheet for each section of this lesson.

Lesson 5

Mass/Weight Measurement Activities

SECTION #1

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Mass is a measure of the amount of material that is contained in an object. The mass of an object can be found by using a balance scale and mass set or mass pieces such as those pictured below. The balance scale will compare the mass of an object in one pan with the mass of a known standard in the other pan.

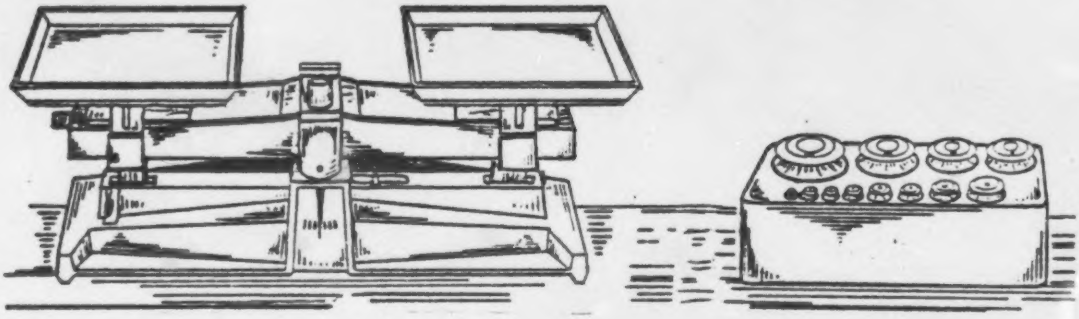


Figure #1

It is very important that you learn how to use the balance scale so that you will be able to compare unknown masses with a mass. First locate the pointer on the balance scale in Figure #1 above. It is located in the center of the balance scale and happens to be pointing straight down in the example in Figure #1.

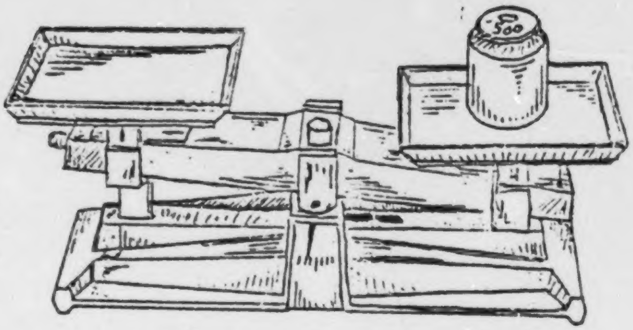


Figure #2

Notice what happens to the pointer in Figure #2 as well as to the pan on the right when a mass piece is placed on the right pan of the balance. The pointer moved to the left.

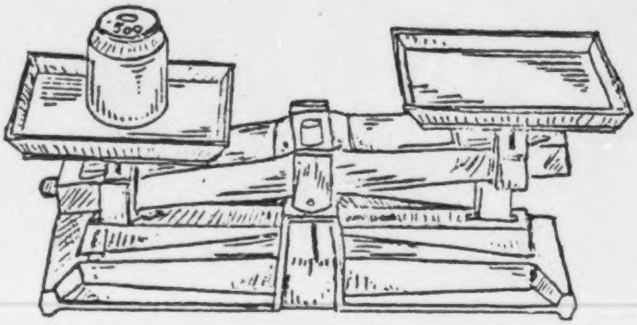
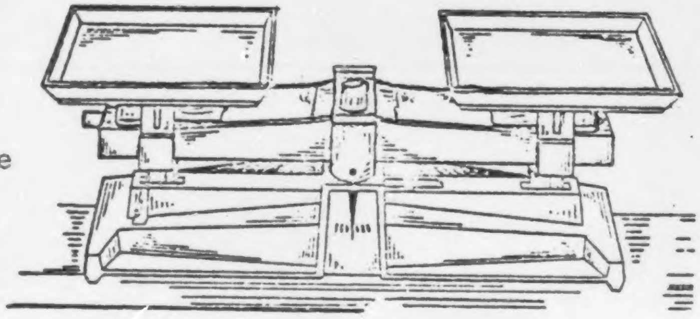


Figure #3

Now observe what happens to the pointer in Figure #3 when [illegible] same mass piece is [illegible] from the right pan and placed on the left pan. The mass moved the pointer to the right and pushed the left pan down.



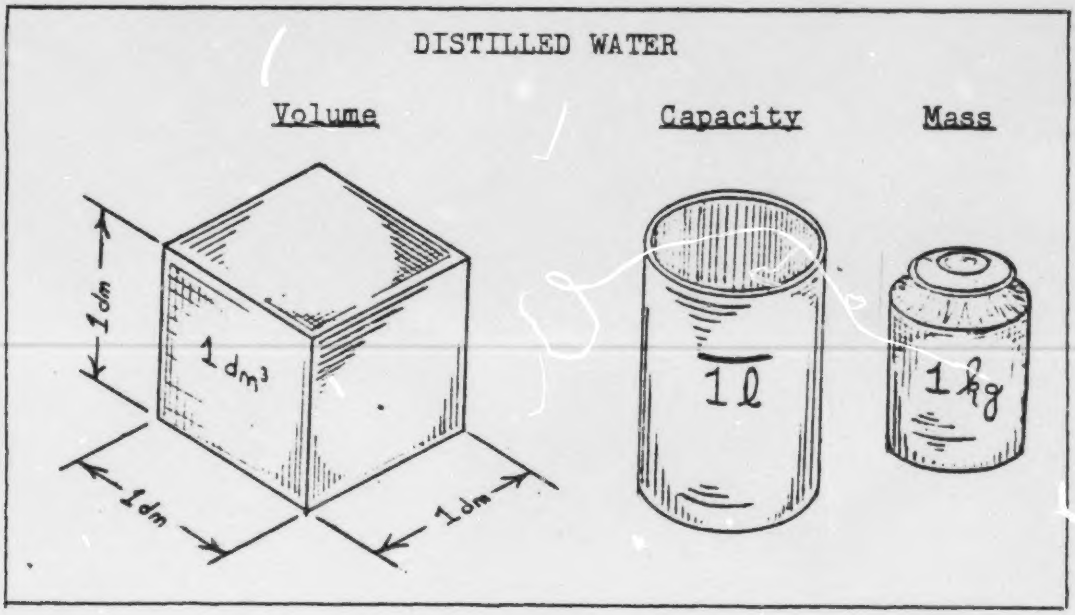
Balanced

The picture to the right shows what should happen when the pans of the balance are empty. Notice how the pointer is on the long line. This means that the scale is balanced.

Key Point If the pointer fails to line up with the long line when both pans are empty, ask your teacher for help.

Kilogram

The kilogram is the basic unit of mass in SI Measurement. The symbol for kilogram is written as the small letters "kg". In SI Measurement, there is a relationship between the volume, capacity and mass of distilled water under standard atmospheric conditions as is shown by the following drawing:

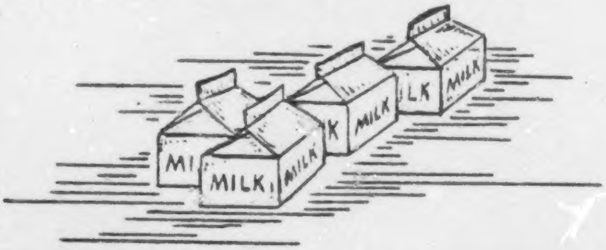


DISTILLED WATER

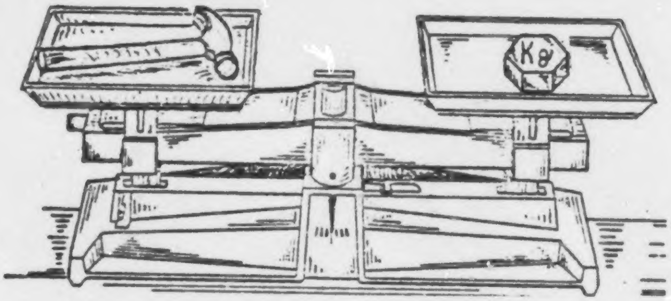
Key Point one cubic decimeter of water = one liter of water = one kilogram

Distilled water is used to show this relationship between volume, capacity and mass because distilled water does not contain varying amounts of minerals which makes some tap (drinking) water heavier or lighter than another. It should be pointed out, though, that there is very little difference between the mass of distilled or tap water.

A kilogram is a large unit of mass. Altogether, 1 four cartons of milk (the kind you can get in your school cafeteria) have a mass of about 1 kilogram.



A hammer also has a mass of approximately 1 kilogram. A hammer placed on one pan of a balance will just about balance a 1 kilogram mass piece which is placed on the other pan as is shown in the example below. Notice that the pointer is pointing straight down which indicates the scale is balanced.



PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item number.

1. 1 ℓ of water = ___?___ kg (number)

2. 1 dm^3 of water = ___?___ kg (number)

3. $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ ℓ of water = 15 kg

4. $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ dm^3 of water = 9 kg

5. 6 ℓ of water = 6 $\underset{\text{(SI symbol)}}{\underline{\quad ? \quad}}$ of mass

6. 12 dm^3 of water = 12 $\underset{\text{(SI symbol)}}{\underline{\quad ? \quad}}$ of capacity

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

SECTION #2

Please look at the clock and record the correct time on the answer sheet. Do this at this time on the blank entitled, Time Started ________.

Laboratory Activities:

One student should go to each work station. Take your workbook, answer sheet, and pencil with you. Remove the following items from your kit:

--Balance scale--which might have been left out from the last activity

--Kilogram (kg) mass--largest mass piece in the kit. It might have been left out from the last activity.

--Plastic liter measure

--Plastic teaspoon

--Container filled with colored water

--Plastic funnel

7. Remove the red and yellow pans from the scale. Find the mass, in kilograms (kg), of the liter measure when it is almost filled with water. Place the 1 kilogram mass piece on the right side of the balance scale. Place the empty liter measure on the left side of the balance. Fill the empty liter measure with colored water from the water container until the scale balances. It may be necessary for you to remove

or add a small amount of water with the plastic teaspoon in order to get the scale to balance properly. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number. CAUTION: Carefully pour the colored water back into the large container with the help of the plastic funnel. Do this on the floor. Return the liter measure, funnel, plastic spoon and the large water container to the kit. Do not return the 1 kilogram mass piece as you will be using it for the next experiment.

8. Place the red and yellow pans back on the scale. Remove Object "N" from your kit. What is the mass, in kilograms (kg), of Object "N"? Place Object "N" on the left pan of the balance and the 1 kilogram mass piece on the right pan. Look at the pointer. Is the mass of Object "N":

(a) less than the 1 kilogram mass piece,
(b) the same as the 1 kilogram mass piece,
or (c) more than the 1 kilogram mass piece?
Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

When you have completed this experiment, place Object "N" back into the kit. Leave the balance, mass set and kilogram mass piece at the work station as they will be used later on in this lesson.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Return to your desk with the pencil, workbook, and answer sheet.

SECTION #3

Please look at the clock and record the correct time on the answer sheet. Do this at this time on the blank entitled, Time Started ________.

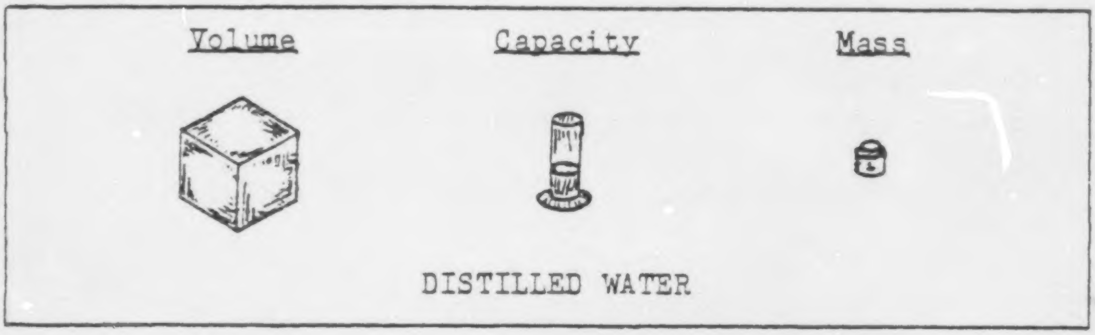
Gram

Sometimes a kilogram is not the best SI unit to use for measuring the mass of an object. This is the case when the object to be measured is much lighter than a kilogram. Therefore a small SI unit of mass is needed when small objects are to be measured. The smaller mass is called a gram. You will recall that it takes one thousand grams to equal one kilogram and that the prefix "kilo" means 1 000.

The symbol for gram is the small letter "g".

Key Point — 1 000 g = 1 kg

The drawing below shows how the SI units of volume, capacity, and mass are related in SI Measurement. You should note that one cubic centimeter ($1\ cm^3$) of distilled water has a capacity of one milliliter (1 mℓ). The mass of this amount of distilled water is 1 gram (1 g).



Key Point — one cubic centimeter of water = one milliliter of water = one gram

PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item number.

9. 1 kg = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ g

10. 4 kg = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ g

11. 9 $\underset{\text{(SI symbol)}}{\underline{\quad ? \quad}}$ = 9 000 g

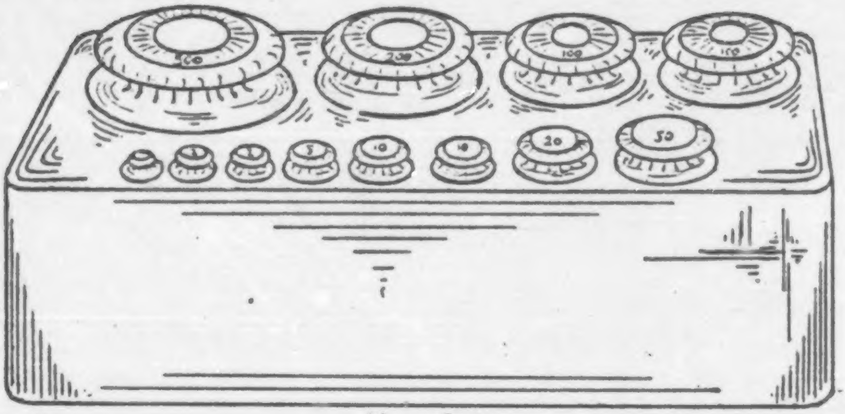
12. $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ kg = 5 000 g

13. 500 mℓ of water = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ g

14. 100 cm^3 of water = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ g

The gram is a small SI unit of mass. One thumbtack has a mass of approximately 1 gram, while a nickel has a mass of approximately 5 grams. Your writing pencil, when it was new, had a mass of about 5 grams.

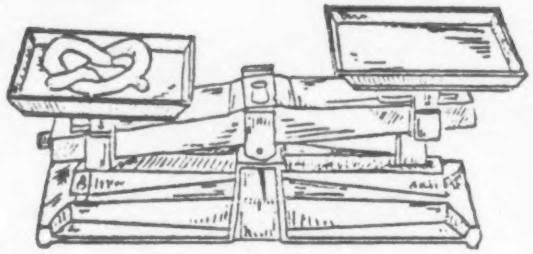
It is important at this time that you learn how to measure the mass of an object in grams by using the balance and the mass pieces which are located in the mass set. The mass set includes the mass pieces shown on the following page:



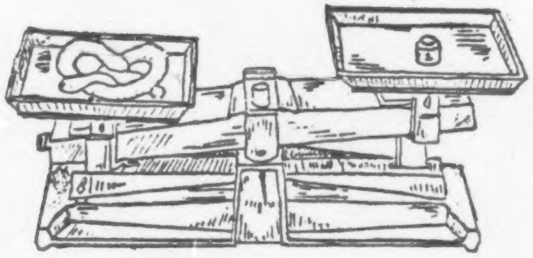
Mass Set

The drawings on the next page show you how to find the mass of one extra thick pretzel. First you place the pretzel on the left pan of the balance (Step 1). Next you follow a simple set of steps by first placing the 1 gram (1 g) mass piece on the right pan (Step 2). Notice that the 1 gram (1 g) mass piece fails to balance the scale, as does the 2 gram (2 g) mass piece (Step 3), and the 5 gram (5 g) mass piece (Step 4). However Step 5 shows that the 10 gram (10 g) mass piece is heavier than the mass of one pretzel. We know then from Steps 4 and 5 that the pretzel has a mass that is somewhere between 5 grams (5 g) and 10 grams (10 g) because the 5 gram (5 g) mass piece is too light, while the 10 gram (10 g) mass piece is too heavy. The mass of the one extra thick pretzel can finally be determined by combining two masses (5 g and 2 g) to balance the scales as shown in Step 6. The mass of the one pretzel is found by adding the two masses (5 g + 2 g) for a total of 7 grams. We can therefore say that one extra thick pretzel has a mass of approximately 7 grams (7 g).

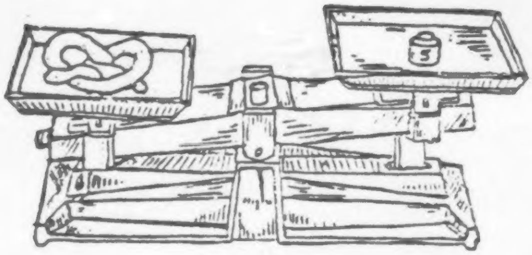
Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.



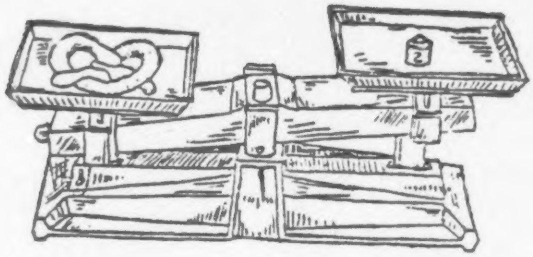
Step #1



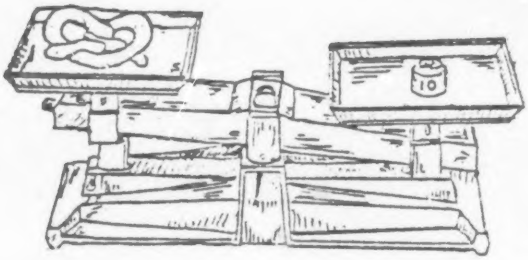
Step #2



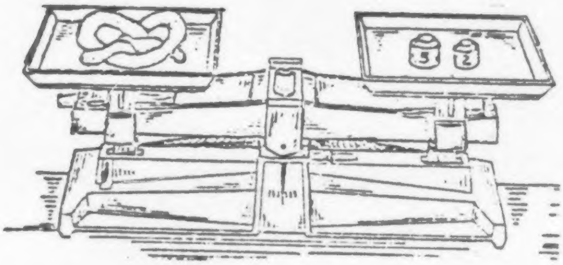
Step #3



Step #4



Step #5



Step #6

*This page is reduced 23% from the original.

SECTION #4

Please look at the clock and record the correct time on the answer sheet. Do this at this time on the blank entitled, Time Started ________.

Laboratory Activities:

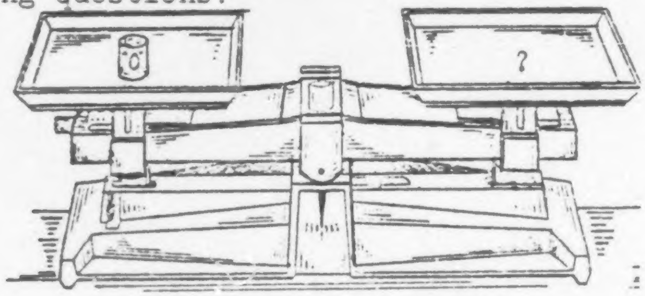
One student should go to each work station. Take your workbook, answer sheet, and pencil with you. Remove the following items from your kit:

- --Balance scale--which might have been left out from the last activity.
- --Mass set--which might have been left out from the last activity.
- --Plastic amber-colored cylinders "O", "P", "R" and "S"

Check your balance to make sure the pointer is on the long line in the center of the scale when the trays are empty. Call your teacher if the scale is not balanced.

Problem Set A:

What is the mass, in grams (g), of Object "O"? Place Object "O" on the left pan of the balance and answer the following questions:



15. Place the 1 gram mass piece on the right pan. Is the mass of Object "O" less than, the same as or more than 1 gram? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 1 gram mass piece from the right pan.

16. Place the 2 gram mass piece on the right pan. Is the mass of Object "O" less than, the same as or more than 2 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 2 gram mass piece from the right pan.

17. Place the 5 gram mass piece on the right pan. Is the mass of Object "O" less than, the same as or more than 5 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 5 gram mass piece from the right pan.

18. Place the 10 gram mass piece on the right pan. Is the mass of Object "O" less than, the same as or more than 10 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 10 gram mass piece from the right pan.

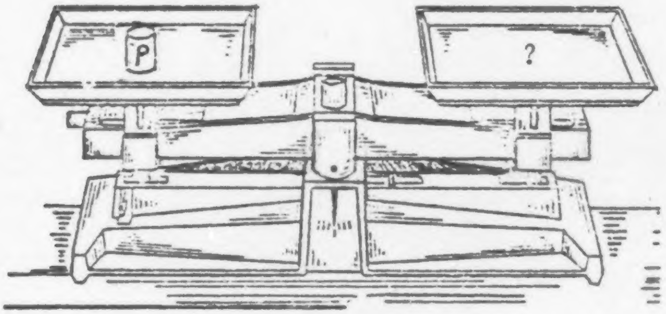
19. If you have measured the mass of Object "O" correctly, you already know that it is the same as one of the measures which you have taken. You are therefore to write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

Remove Object "O" from the pan of the balance. Leave the balance at the work station for the next problem set.

Problem Set B:

What is the mass, in grams (g), of Object "P"?

Place Object "P" on the left pan of the balance and answer the following questions:



20. Place the 1 gram mass piece on the right pan. Is the mass of Object "P" less than, the same as or more than 1 gram? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 1 gram mass piece from the right pan.

21. Place the 2 gram mass piece on the right pan. Is the mass of Object "P" less than, the same as or more than 2 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 2 gram mass piece from the right pan.

22. Place the 5 gram mass piece on the right pan. Is the mass of Object "P" less than, the same as or more than 5 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 5 gram mass piece from the right pan.

23. Place the 10 gram mass piece on the right pan. Is the mass of Object "P" less than, the same as or more than 10 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 10 gram mass piece from the right pan.

24. Place the 20 gram mass piece on the right pan. Is the mass of Object "P" less than, the same as or more than 20 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 20 gram mass piece from the right pan.

25. Place the 10 gram mass piece and 1 gram mass piece on the right pan. Is the mass of Object "P" less than, the same as or more than 11 grams (10 g + 1 g = 11 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 10 gram and 1 gram mass pieces from the right pan.

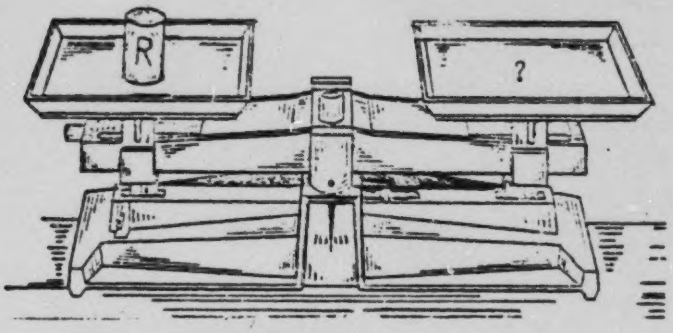
26. If you have measured the mass of Object "P" correctly, you already know that it is the same as one of the measures which you have taken. You are therefore to write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

Remove Object "P" from the pan of the balance. Leave the balance at the work station for the next problem set.

Problem Set C:

What is the mass, in grams (g), of Object "R"?

Place Object "R" on the left pan of the balance and answer the following questions:



27. Place the 10 gram mass piece on the right pan. Is the mass of Object "R" less than, the same as or more than 10 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 10 gram mass piece from the right pan.

28. Place the 20 gram mass piece on the right pan. Is the mass of Object "R" less than, the same as or more than 20 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Do not remove the 20 gram mass piece from the right pan as it will be used in the next question.

29. Place the 10 gram mass piece on the right pan with the 20 gram mass piece. Is the mass of Object "R" less than, the same as or more than 30 grams (10 g + 20 g = 30 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove only the 10 gram mass piece from the right pan. Do not remove the 20 gram mass piece as it will be used in the next question.

30. Place the 1 gram mass piece on the right pan with the 20 gram mass piece. Is the mass of Object "R" less than, the same as or more than 21 grams (20 g + 1 g = 21 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove only the 1 gram mass piece from the right pan. Do not remove the 20 gram mass piece as it will be used in the next question.

31. Place the 2 gram mass piece on the right pan with the 20 gram mass piece. Is the mass of Object "R" less than, the same as or more than 22 grams (20 g + 2 g = 22 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Do not remove the 20 gram and 2 gram mass pieces from the right pan as both will be used in the next question.

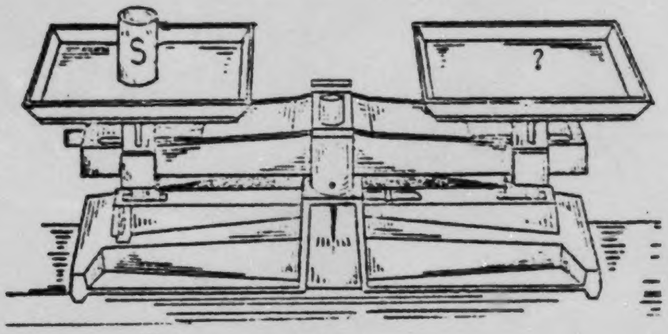
32. Place the 1 gram mass piece on the right pan with the 20 gram and 2 gram mass pieces. Is the mass of Object "R" less than, the same as or more than 23 grams (20 g + 2 g + 1 g = 23 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 20 gram, 2 gram and 1 gram mass pieces from the right pan.

33. If you have measured the mass of Object "R" correctly, you already know that it is the same as one of the measures which you have taken. You are therefore to write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

Remove the Object "R" from the pan of the balance. Leave the balance at the work station for the next problem set.

Problem Set D:

What is the mass, in grams (g), of Object "S"? This activity applies to an object whose mass is more than 50 grams. Place Object "S" on the left pan of the balance and answer the following questions:



34. Place the 100 gram mass piece on the right pan. Is the mass of Object "S" less than, the same as or more than 100 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 100 gram mass piece from the right pan.

35. Place the 200 gram mass piece on the right pan. Is the mass of Object "S" less than, the same as or more than 200 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Do not remove the 200 gram mass piece from the right pan as it will be used in the next question.

36. Place the 50 gram mass piece on the right pan with the 200 gram mass piece. Is the mass of Object "S" less than, the same as or more than 250 grams (200 g + 50 g = 250 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove only the 50 gram mass piece from the right pan. Do not remove the 200 gram mass piece as it will be used in the next question.

37. Place the 20 gram mass piece on the right pan with the 200 gram mass piece. Is the mass of Object "S" less than, the same as or more than 220 grams (200 g + 20 g = 220 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Do not remove the 200 gram and 20 gram mass pieces from the right pan as both will be used in the next question.

38. Place the 1 gram mass piece on the right pan with the 200 gram and 20 gram mass pieces. Is the mass of Object "S" less than, the same as or more than 221 grams (200 g + 20 g + 1 g = 221 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number. Remove the 200 gram, 20 gram and 1 gram mass pieces from the right pan.

39. If you have measured the mass of Object "S" correctly, you already know that it is the same as one of the measures which you have taken. You are therefore to write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

Remove Object "S" from the pan of the balance.

Remove the plastic amber-colored cylinders "O", "P", "R" and "S" to the kit. Leave the balance, the mass set and the kilogram mass piece at the work station for they will be used by the next student replacing you at the work station.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Return to your desk with pencil, workbook, and answer sheet.

Check all your answers with the KEY.

Answer Sheet for

Lesson 5--Laboratory Activity

Student # ________________ Teacher # ________________

SECTION #1--Time Started ______________

1. 1 ℓ of water = ________ kg
   (number)

2. 1 dm^3 of water = ________ kg
   (number)

3. ________ ℓ of water = 15 kg
   (number)

4. ________ dm^3 of water = 9 kg
   (number)

5. 6 ℓ of water = 6 ____________ of mass
   (SI symbol)

6. 12 dm^3 of water = 12 ____________ of capacity.
   (SI symbol)

Time Completed ______________

SECTION #2--Time Started ______________

7. Liter measure filled with water has a mass of

   ________ ____________.
   (number) (SI symbol)

(Section #2 continued on next page)

8. Object "N" (Circle the letter before the correct statement.)

a. Object "N" has less mass than does the 1 kilogram mass piece.

b. Object "N" has the same mass as does the 1 kilogram mass piece.

c. Object "N" has more mass than does the 1 kilogram mass piece.

Time Completed ______________

SECTION #3--Time Started ________________

9. 1 kg = ________ g
(number)

10. 4 kg = ________ g
(number)

11. 9 ___________ = 9 000 g
(SI symbol)

12. ________ kg = 5 000 g
(number)

13. 500 mℓ of water = ________ g
(number)

14. 100 cm^3 of water = ________ g
(number)

Time Completed ______________

SECTION #4--Time Started ________________

Problem Set A: (Circle the letter before the correct statement for each of the following questions.)

15.

a. Object "O" has less mass than does the 1 gram mass piece.

b. Object "O" has the same mass as does the 1 gram mass piece.

c. Object "O" has more mass than does the 1 gram mass piece.

16.

a. Object "O" has less mass than does the 2 gram mass piece.

b. Object "O" has the same mass as does the 2 gram mass piece.

c. Object "O" has more mass than does the 2 gram mass piece.

17.

a. Object "O" has less mass than does the 5 gram mass piece.

b. Object "O" has the same mass as does the 5 gram mass piece.

c. Object "O" has more mass than does the 5 gram mass piece.

18.

a. Object "O" has less mass than does the 10 gram mass piece.

b. Object "O" has the same mass as does the 10 gram mass piece.

c. Object "O" has more mass than does the 10 gram mass piece.

19. Object "O" was found to have a mass of

________ __________.
(number) (SI symbol)

Problem Set B: (Circle the letter before the correct statement for each of the following questions.)

20.

a. Object "P" has less mass than does the 1 gram mass piece.

b. Object "P" has the same mass as does the 1 gram mass piece.

c. Object "P" has more mass than does the 1 gram mass piece.

21.

a. Object "P" has less mass than does the 2 gram mass piece.

b. Object "P" has the same mass as does the 2 gram mass piece.

c. Object "P" has more mass than does the 2 gram mass piece.

22.

a. Object "P" has less mass than does the 5 gram mass piece.

b. Object "P" has the same mass as does the 5 gram mass piece.

c. Object "P" has more mass than does the 5 gram mass piece.

23.

a. Object "P" has less mass than does the 10 gram mass piece.

b. Object "P" has the same mass as does the 10 gram mass piece.

c. Object "P" has more mass than does the 10 gram mass piece.

24.

a. Object "P" has less mass than does the 20 gram mass piece.

b. Object "P" has the same mass as does the 20 gram mass piece.

c. Object "P" has more mass than does the 20 gram mass piece.

25.

a. Object "P" has less mass than do the 11 gram mass pieces.

b. Object "P" has the same mass as do the 11 gram mass pieces.

c. Object "P" has more mass than do the 11 gram mass pieces.

26. Object "P" was found to have a mass of

________ __________.
(number) (SI symbol)

Problem Set C: (Circle the letter before the correct statement for each of the following questions.)

27.

a. Object "R" has less mass than does the 10 gram mass piece.

b. Object "R" has the same mass as does the 10 gram mass piece.

c. Object "R" has more mass than does the 10 gram mass piece.

28.

a. Object "R" has less mass than does the 20 gram mass piece.

b. Object "R" has the same mass as does the 20 gram mass piece.

c. Object "R" has more mass than does the 20 gram mass piece.

29.

a. Object "R" has less mass than does the 30 gram mass piece.

b. Object "R" has the same mass as does the 30 gram mass piece.

c. Object "R" has more mass than does the 30 gram mass piece.

30.

a. Object "R" has less mass than do the 21 gram mass pieces.

b. Object "R" has the same mass as do the 21 gram mass pieces.

c. Object "R" has more mass than do the 21 gram mass pieces.

31.

a. Object "R" has less mass than do the 22 gram mass pieces.

b. Object "R" has the same mass as do the 22 gram mass pieces.

c. Object "R" has more mass than do the 22 gram mass pieces.

32.

a. Object "R" has less mass than do the 23 gram mass pieces.

b. Object "R" has the same mass as do the 23 gram mass pieces.

c. Object "R" has more mass than do the 23 gram mass pieces.

33. Object "R" was found to have a mass of

________ ____________.
(number) (SI symbol)

Problem Set D: (Circle the letter before the correct statement for each of the following questions.)

34.

a. Object "S" has less mass than does the 100 gram mass piece.

b. Object "S" has the same mass as does the 100 gram mass piece.

c. Object "S" has more mass than does the 100 gram mass piece.

35.

a. Object "S" has less mass than does the 200 gram mass piece.

b. Object "S" has the same mass as does the 200 gram mass piece.

c. Object "S" has more mass than does the 200 gram mass piece.

36.

a. Object "S" has less mass than do the 250 gram mass pieces.

b. Object "S" has the same mass as do the 250 gram mass pieces.

c. Object "S" has more mass than do the 250 gram mass pieces.

37.

a. Object "S" has less mass than do the 220 gram mass pieces.

b. Object "S" has the same mass as do the 220 gram mass pieces.

c. Object "S" has more mass than do the 220 gram mass pieces.

38.

a. Object "S" has less mass than do the 221 gram mass pieces.

b. Object "S" has the same mass as do the 221 gram mass pieces.

c. Object "S" has more mass than do the 221 gram mass pieces.

39. Object "S" was found to have a mass of

__________ ______________.
(number) (SI symbol)

Time Completed ________________

TEMPERATURE
IN
SI MEASUREMENT

Lesson 6

LABORATORY ACTIVITIES

General Directions

Please do not write in this booklet. A special answer sheet, which will be supplied by your teacher, will be used to record your answers. You will need to supply your own soft lead pencil.

You will be asked to record the time when you start an activity (Time Started) and the time when you complete an activity (Time Completed). You will be asked to do this several times throughout this lesson. Please take special care to record these times on your answer sheet for each section of this lesson.

Lesson 6

Temperature Measurement Activities

SECTION #1

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Temperature in SI Measurement is usually measured with a Celsius thermometer. Figure #1 is a drawing of a Celsius thermometer with its various parts labeled. The glass tube contains a red liquid that expands and raises as the temperature increases and contracts or lowers as the temperature decreases. The scale on the thermometer is used to indicate the position of the liquid and thus the temperature. The capital letter "C" at the top of the thermometer is the symbol for Celsius.

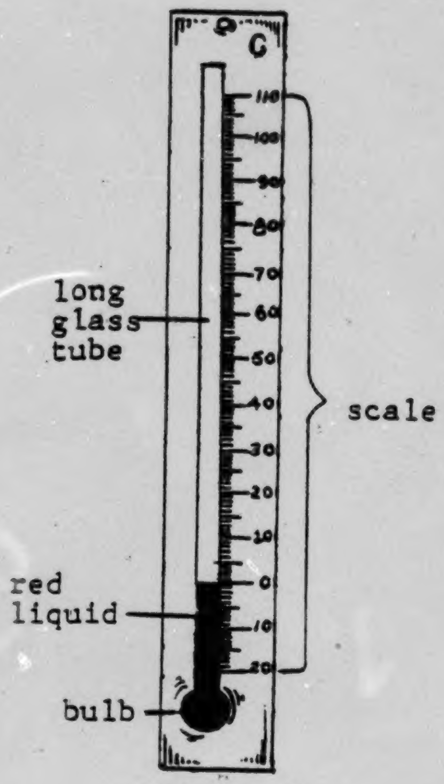


Figure #1

Did you notice the lines on the scale of the thermometer? Each line represents a number, but not all lines have numbers next to them.

Let's take a closer look at the part of the thermometer between 0 and 10 which is shown in Figure #2. Count the spaces between the 0 and the 10. You should have counted 10 spaces.

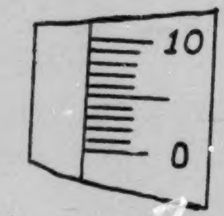


Figure #2

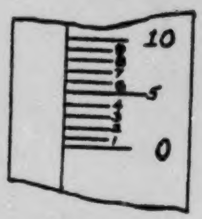
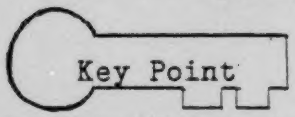


Figure #3

The first line above the line marked 0 stands for 1 as is shown in Figure #3. The next line stands for 2, and so on. Notice that line 5, which is half way between 0 and 10, is a little longer than the rest of the lines.

1. Look at your answer sheet. Next to number 1 you see a section of a Celsius temperature scale. Place the number the line stands for to the right of each line on the scale.

The units for measuring temperature are called degrees. Each line that you see on the scale of the Celsius thermometer stands for 1 degree. The small raised circle, "°" is the symbol that is used to represent degree.



When you use the Celsius scale to measure temperature always write °C after the number which is the symbol for degree Celsius. This identifies the scale and the SI unit used.

The drawing in Figure #4 shows part of a Celsius thermometer. The liquid is two lines above 60. This thermometer shows a temperature of 62 °C.

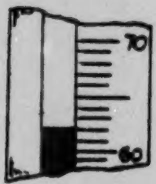


Figure #4

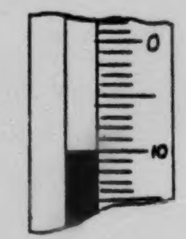


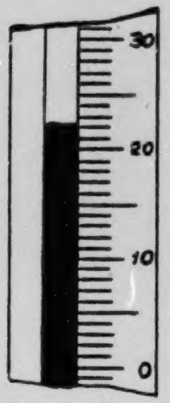
Figure #5

There are times when the temperature is below zero. Figure #5 shows a Celsius thermometer which reads, "10 °C below zero," or is read as "-10 °C."

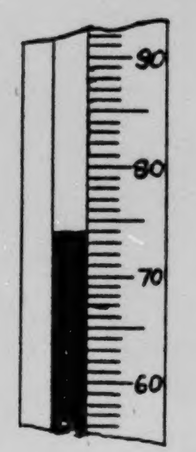
PRACTICE PROBLEMS:

Four drawings of Celsius thermometers are provided for clarification of measuring temperature in this SI unit. What temperature does each thermometer show? Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

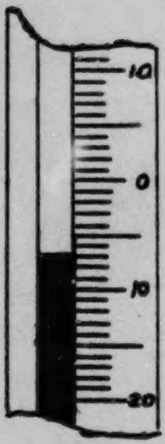
2.



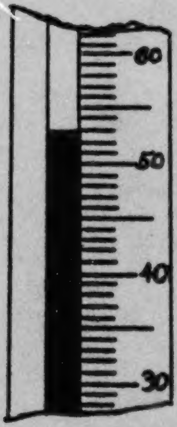
3.



4.



5.



Finally, temperature measurements will be more accurate if you follow these Key Points:

1. When measuring the temperature of a liquid, be sure the bulb which is located at the bottom of the thermometer is in the liquid.

2. Always hold the thermometer by the metal part. If your fingers are on the bulb, the heat from them can make the red liquid go up or down.

Laboratory Activities:

6. Do not use a thermometer to answer this question. Estimate the temperature of your classroom in Celsius units. Write your answer and the proper SI symbol on the answer sheet beside the corresponding item numbers.

7. Do not use a thermometer to answer this question. Estimate the temperature of a Celsius thermometer that is placed in an ice-filled container for 60 seconds. The container with ice is displayed at the front of the classroom. Make an estimate of the temperature by observing the ice-filled container from your desk. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.

8. Do not use a thermometer to answer this question. Estimate the temperature of a Celsius thermometer, if you were holding the bulb of the thermometer between the palms of your hands for 60 seconds. The bulb, in this case, would be touching your palms. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.

9. Do not use a thermometer to answer this question. Estimate the temperature of a Celsius thermometer that is placed in the heated water of a coffee pot for 60 seconds. The coffee pot with heated water is displayed at the front of the classroom. Make an estimate of the temperature by observing the coffee pot from your desk. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

SECTION #2

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Laboratory Activities:

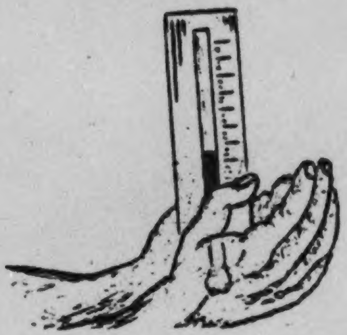
One student should go to each work station. Take your pencil, workbook and answer sheet with you. Remove the Celsius thermometer and container "D" (coffee can) from your kit.

10. Measure the temperature of your classroom by using a Celsius thermometer.
    Key Point Hold the thermometer by the metal part. Do not touch the glass. Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

11. You should next measure the temperature of the container labeled "D" with the Celsius thermometer after it is filled with ice. Fill container "D" with the ice provided by your teacher. Place the Celsius thermometer in the container labeled "D" for 60 seconds or for as long as it takes to count (silently) from 1 to 100. Count at a normal pace. Remove the thermometer from the container of ice and record your answer and the proper SI symbol on the answer sheet beside the corresponding item

number. Pour the ice from the container labeled "D" back into your teacher's ice container.

12. Next, measure your body temperature by placing the Celsius thermometer between the palms of your hands. The picture at the right indicates how the bulb of the thermometer should be placed in the palms of your hands. Be certain that the bulb of the thermometer is touching the palms of your hands. Hold the thermometer in place for 60 seconds or for as long as it takes you to count (silently) from 1 to 100. Count at a normal pace. Record the answer and the proper SI symbol on the answer sheet beside the corresponding item number.



13. Measure the temperature of the heated water inside the coffee pot that is placed at the front of the classroom with a Celsius thermometer. CAUTION: The coffee pot as well as the heated water inside is VERY, VERY HOT! Remove the lid from the coffee pot and carefully lower the Celsius thermometer into the water by holding onto the wire which has been attached to

the thermometer. Hold the thermometer in the water for 60 seconds or for as long as it takes you to count (silently) from 1 to 100. The thermometer will not be ruined if it is left in the water longer than 60 seconds. Count at a normal pace. Remove the thermometer from the coffee pot and record your answer and the proper SI symbol on the answer sheet beside the corresponding item number. Carefully place the lid back on the coffee pot. Return to your work station with the Celsius thermometer.

When you have completed the activities, return the Celsius thermometer and container "D" to the kit.

Please look at the clock and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Return to your desk with pencil, workbook and answer sheet.

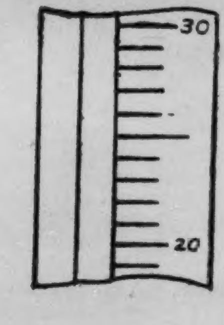
Check all your answers with the KEY. You will find that the answers are not supplied for the Estimate questions. There are no wrong answers for the Estimate questions. However, notice the difference, if any, between your Estimated measurement answer and the actual Measurement answer.

Answer Sheet for
Lesson 6--Laboratory Activity

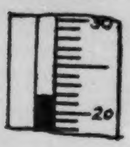
Student # ____________ Teacher # ____________

SECTION #1--Time Started ____________

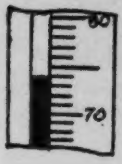
1.



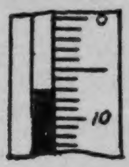
2. ________



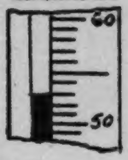
3. ________



4. ________



5. ________



SECTION #2--Time Started ____

	ESTIMATE				MEASUREMENT	
6.	________ (number)	________ (SI symbol)	←Compare→ (classroom)	10.	________ (number)	________ (SI symbol)
7.	________ (number)	________ (SI symbol)	←Compare→ (ice)	11.	________ (number)	________ (SI symbol)
8.	________ (number)	________ (SI symbol)	←Compare→ (palms)	12.	________ (number)	________ (SI symbol)
9.	________ (number)	________ (SI symbol)	←Compare→ (coffee pot)	13.	________ (number)	________ (SI symbol)

SECTION #1--

Time Completed ____________

SECTION #2--

Time Completed ______

APPENDIX E

Instructional Approach B--Simulated Activities

LINEAR
IN
SI MEASUREMENT

Lesson 3

SIMULATED ACTIVITIES

General Directions

Please do not write in this booklet. A special answer sheet, which will be supplied by your teacher, will be used to record your answers. You will need to supply your own soft lead pencil.

You will be asked to record the time when you start an activity (Time Started) and the time when you complete an activity (Time Completed). Please take special care to record these times on your answer sheet.

Lesson 3

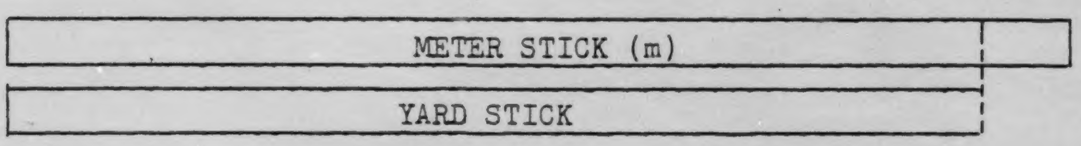
Linear Measurement Activities

SECTION #1

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

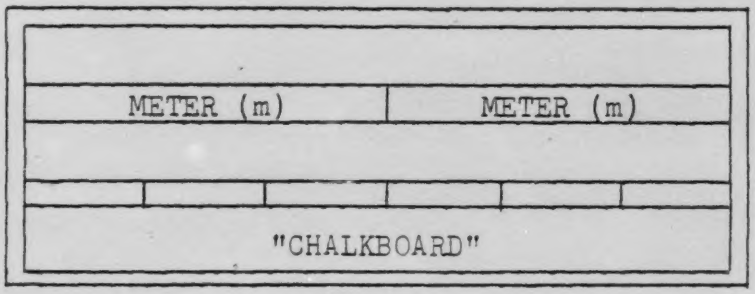
Meter

The meter is the basic unit of length in SI Measurement. The symbol for meter is the small letter "m". The meter is used to measure length. A meter stick is slightly longer than a yard stick.

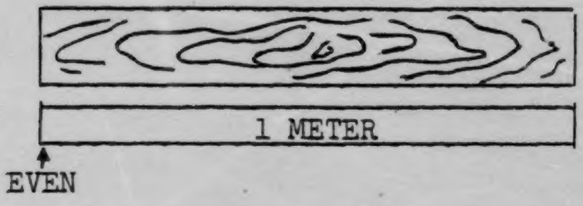


Take a good look at the length of one meter. Your teacher will hold a meter stick up for you to look at. The distance from one end of the meter stick to the other end is one meter.

The unit meter is frequently used when a person has to find the length of long objects. For example, to measure the length of a chalkboard it would be easier and faster to use a meter stick than a smaller measuring stick.



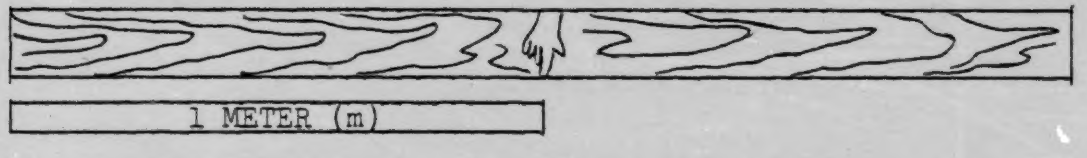
Now let's suppose that you are to measure the length of the piece of lumber shown below with a meter stick. Notice the way the meter stick is placed next to the board with the left end of the stick even with the left end of the piece of lumber.



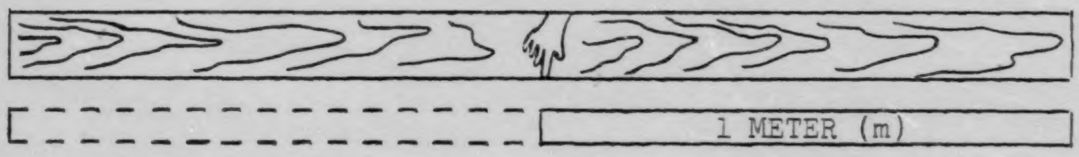
This piece of lumber measures one meter (1 m) long. This would be written on the answer sheet as ___1___ (number) ___m___ (SI symbol).

What is the best procedure to use when you have to measure a piece of lumber that is two or three meters long?

The first thing you do is to place the meter stick next to the piece of lumber and line up the end of the meter stick with the left end of the board.



Next, place your finger or a pencil mark on the board so that it is even with the right end of the meter stick. Move the meter stick along the board until the left end of the meter stick is at the spot on the board marked by your finger or the pencil line.



The piece of lumber on the preceding page measures exactly two meters (2 m) long. This would be recorded on the answer sheet as 2 (number) m (SI symbol).

SECTION #2

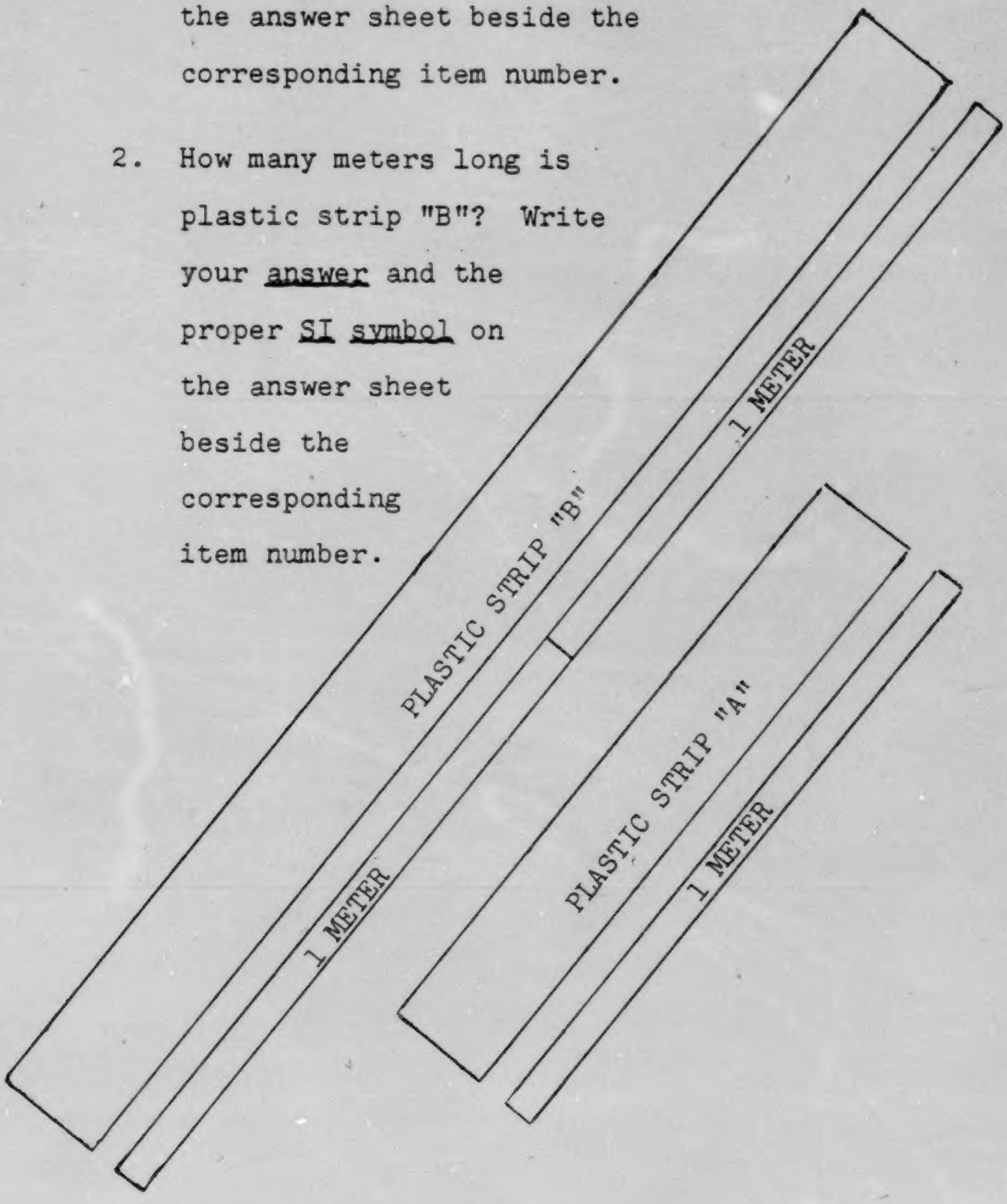
Simulated Activities:

You will recall from the introduction that the meter stick which your teacher held up was a little longer than a yard stick. The meter stick is on display at the front of the classroom. In the activities that follow, it is important that you realize that the objects being measured are one-tenth their actual length. The size paper this was printed on along with the actual length of a meter, prevented our drawing the meter stick and the plastic strips full size.

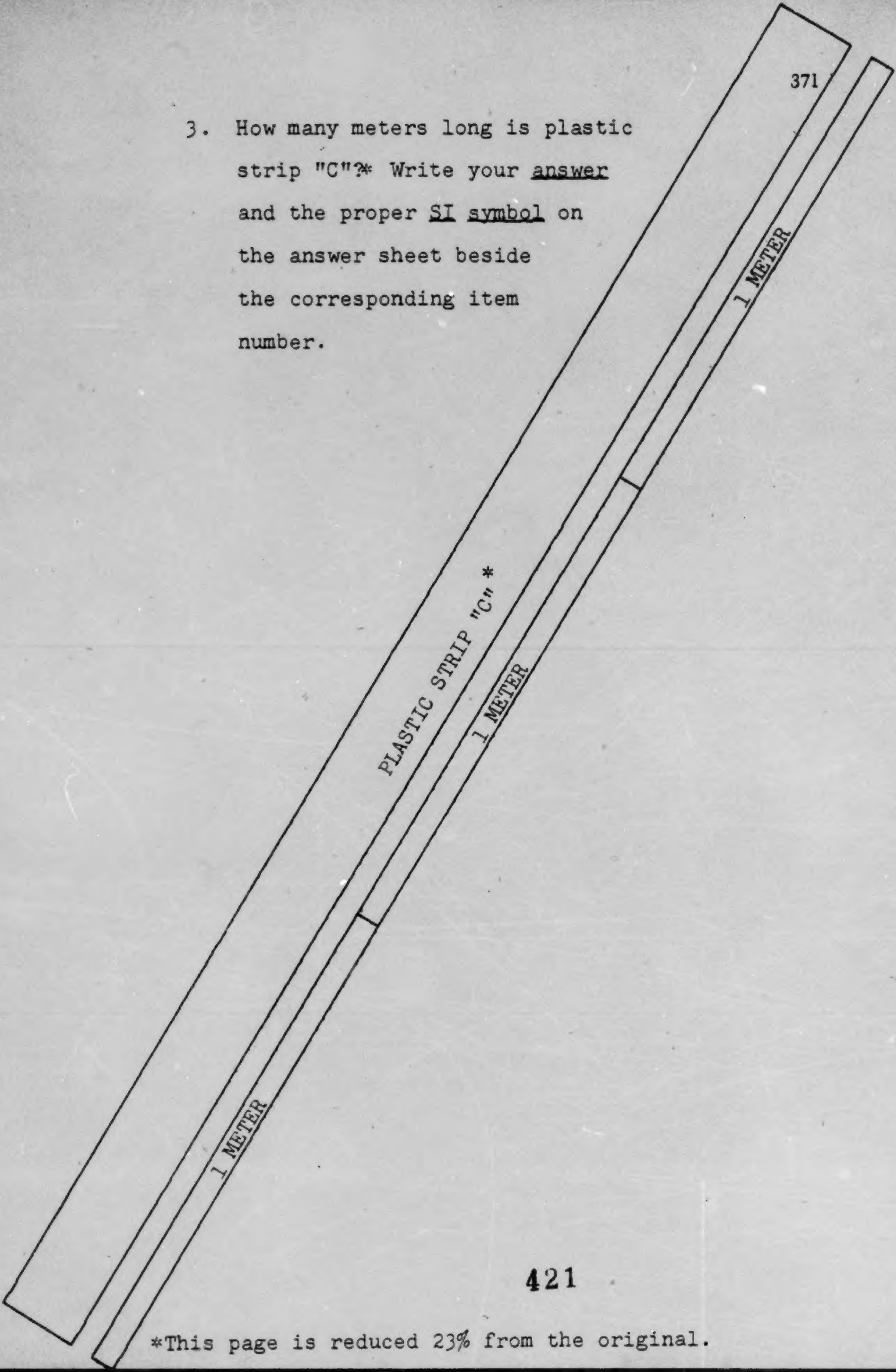
Below and on the next page you see pictures of three plastic strips of different lengths which are one-tenth of their actual length.

1. How many meters long is plastic strip "A"? Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

2. How many meters long is plastic strip "B"? Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.


PLASTIC STRIP "B"
1 METER
1 METER
PLASTIC STRIP "A"
1 METER

3. How many meters long is plastic strip "C"?* Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

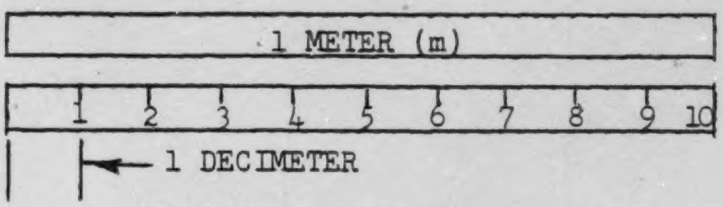

PLASTIC STRIP "C" *
1 METER
1 METER
1 METER

*This page is reduced 23% from the original.

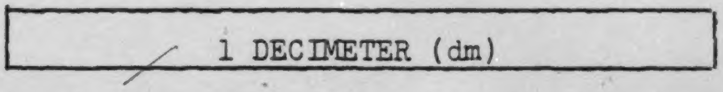
SECTION #3

Decimeter

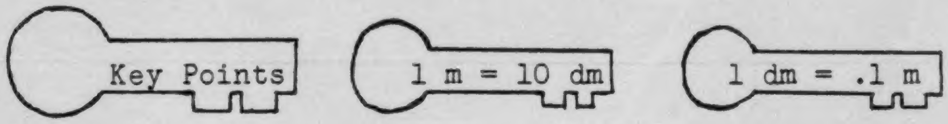
There are smaller SI Measures than the meter which can be used to measure small objects. Since the SI System of Measurement is a decimal system (based on 10), smaller units are found by dividing the meter into 10 parts with each part being the same length, and then dividing each of those parts into 10 equal parts, and so on.



When the meter is divided into 10 equal parts, each of the 10 parts is called a decimeter. Your teacher will hold up a decimeter stick for you to look at. The symbol for decimeter is the small letters "dm". A decimeter is actually this long:



The decimeter is one-tenth or .1 meter. Some of you will find that it is about the width of your hand.



The decimeter is seldom used in measuring objects which are quite long. It does have an important use, though, and you will learn about that when you study volume/capacity.

PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item numbers.

4. 5 m = ___?___ dm

5. 10 m = ___?___ dm

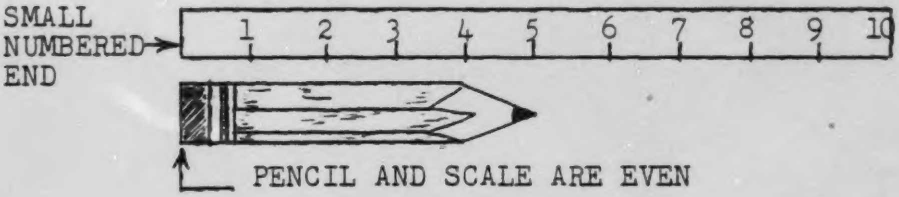
6. 13 m = ___?___ dm

7. 30 dm = ___?___ m

8. 70 dm = ___?___ m

9. 140 dm = ___?___ m

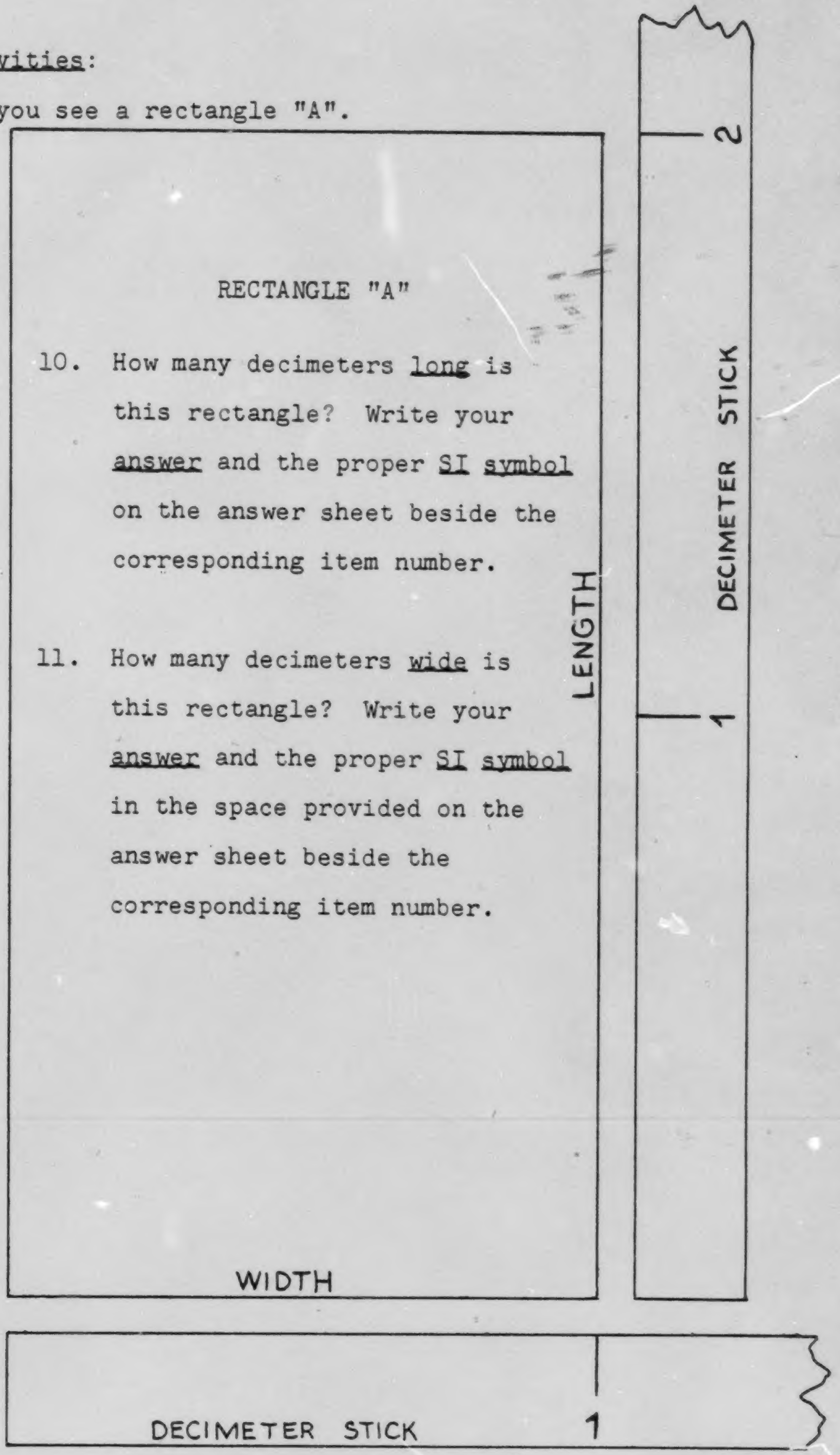
Key Point It is very important from now on that when you use a scale to measure something you place the end with the smallest number even with the end of the object you are measuring. A good example would be to measure the length of a pencil as indicated below. Notice that the end of the scale (small numbered end) is even with the end of the pencil.



SECTION #4

Simulated Activities:

Below you see a rectangle "A". Part of a decimeter stick has been positioned next to its width and length. The markings on the decimeter stick are shown true size.*



RECTANGLE "A"

10. How many decimeters long is this rectangle? Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

11. How many decimeters wide is this rectangle? Write your answer and the proper SI symbol in the space provided on the answer sheet beside the corresponding item number.

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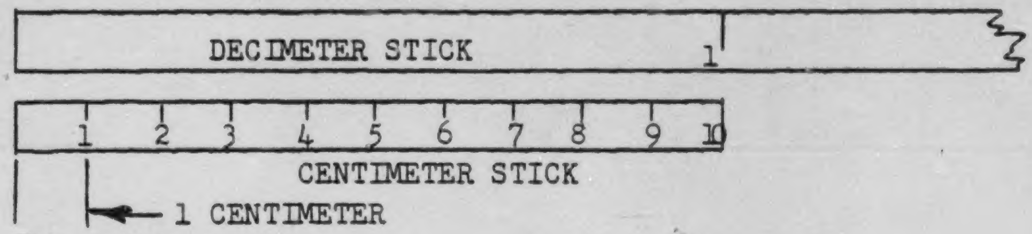
*This page is reduced 15% from the original.

SECTION #5

Centimeter

When the decimeter is divided into 10 equal parts, each of the 10 small parts is equal to one centimeter. Your teacher will hold up a short orange scale which is divided into centimeters. Use the small letters "cm" as a symbol which stands for the word, "centimeter."

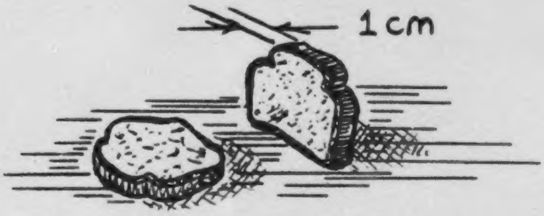


Key Point 1 dm = 10 cm

"Centi" means "hundredth." The centimeter is an SI Measure of length that is equal to one-hundredth or .01 meter.

Key Point 1 m = 10 dm = 100 cm

The thickness of one slice of sandwich bread is approximately equal to 1 cm or 1 centimeter.



At the present time you will probably use the centimeter unit more than any other SI unit we have talked about.

PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item numbers.

12. 1 dm = __?__ cm
13. __?__ cm = 5 dm
14. __?__ cm = 10 dm
15. __?__ m = 300 cm
16. __?__ cm = 2 m
17. 400 cm = __?__ m

Key Point Remember that when you are using a scale you should place the end with the smallest number even with the left end of the object which you are measuring.

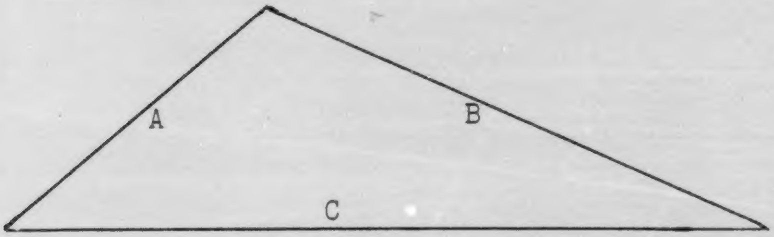
SECTION #6

Simulated Activities:

18. Estimate the length of side A of the triangle pictured below, in centimeters. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number in the ESTIMATE column.

19. Estimate the length of side B of the triangle pictured below, in centimeters. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number in the ESTIMATE column.

20. Estimate the length of side C of the triangle pictured below, in centimeters. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number in the ESTIMATE column.

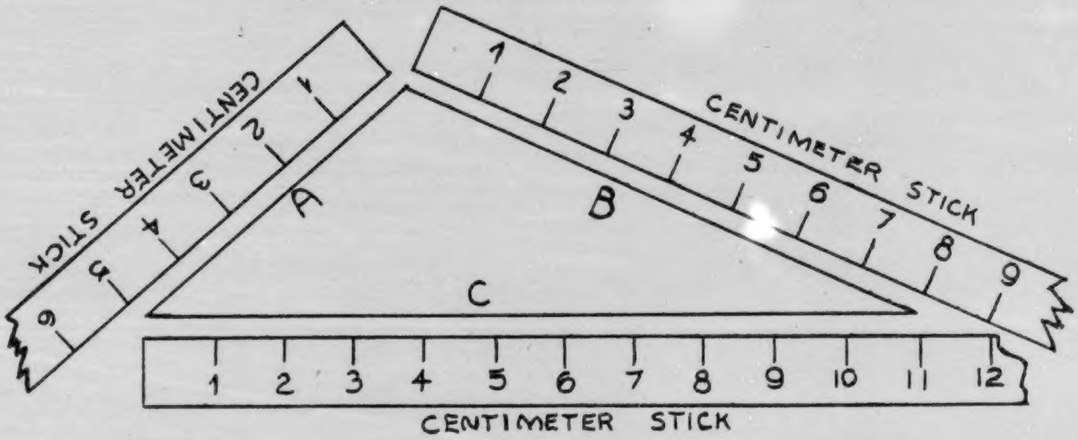


Below you see a picture of a triangle with three true size centimeter sticks positioned next to each of its sides.

21. How many centimeters match the length of side A? Write your answer and the proper SI symbol in the space provided on the answer sheet beside the corresponding item number in the MEASUREMENT column.

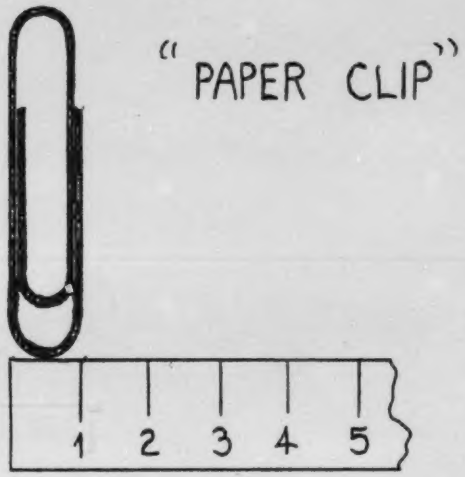
22. How many centimeters match the length of side B? Write your answer and the proper SI symbol in the space provided on the answer sheet beside the corresponding item number in the MEASUREMENT column.

23. How many centimeters match the length of side C? Write your answer and the proper SI symbol in the space provided on the answer sheet beside the corresponding item number in the MEASUREMENT column.

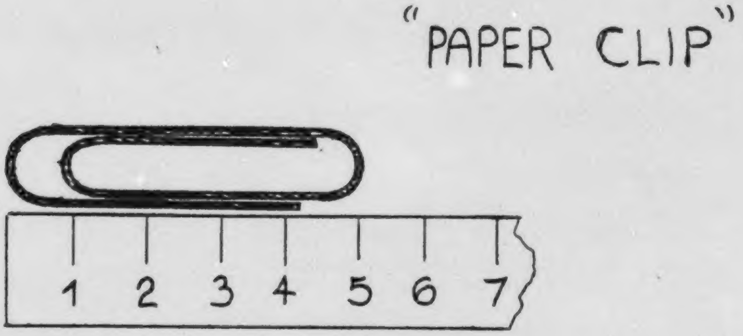

CENTIMETER STICK
1
2
3
4
5
6
A
B
C
CENTIMETER STICK
1
2
3
4
5
6
7
8
9
1
2
3
4
5
6
7
8
9
10
11
12
CENTIMETER STICK

Use the centimeter stick pictured in each of the exercises which follow to name the length or width of the object to the nearest centimeter. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

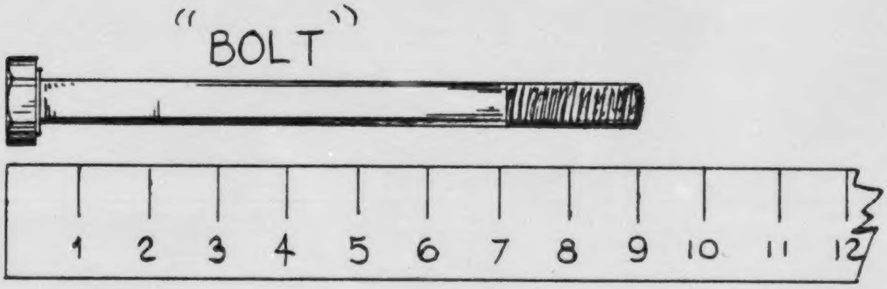
24.


"PAPER CLIP"
1
2
3
4
5

25.


"PAPER CLIP"
1
2
3
4
5
6
7

26.


"BOLT"
1
2
3
4
5
6
7
8
9
10
11
12

Place an "X" on the centimeter sticks which are drawn on the answer sheet at the location of the length called for below. Be sure that the item number on the answer sheet corresponds with the item number below when you are recording your answer.

27. 10 cm

28. 16 cm

SECTION #7

Kilometer

Just as there are smaller SI units such as the centimeter, there are also larger SI units used for measuring length. The unit most often used to measure long distances is the kilometer. The kilometer is a unit of length equal to 1 000 meters. "Kilo" means "one thousand." The symbol for kilometer is the small letters "km".

Key Point 1 km = 1 000 m

The kilometer is about the same distance as going around a baseball diamond $9\frac{1}{4}$ times. The distance from McDonald's to Reese Elementary School is $1\frac{1}{2}$ kilometers; to Ridgeview Elementary School is $3\frac{1}{2}$ kilometers; and to Southeast Elementary School is $2\frac{1}{4}$ kilometers.

PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item numbers.

29. 2 km = __?__ m
30. 32 km = __?__ m
31. 8 km = __?__ m
32. 4 000 m = __?__ km
33. 16 000 m = __?__ km
34. 9 000 m = __?__ km

Several problems related to distance are given below. You are to find the correct distance by using the map which is provided. Please record the distance in kilometers and the other information requested on the separate answer sheet.

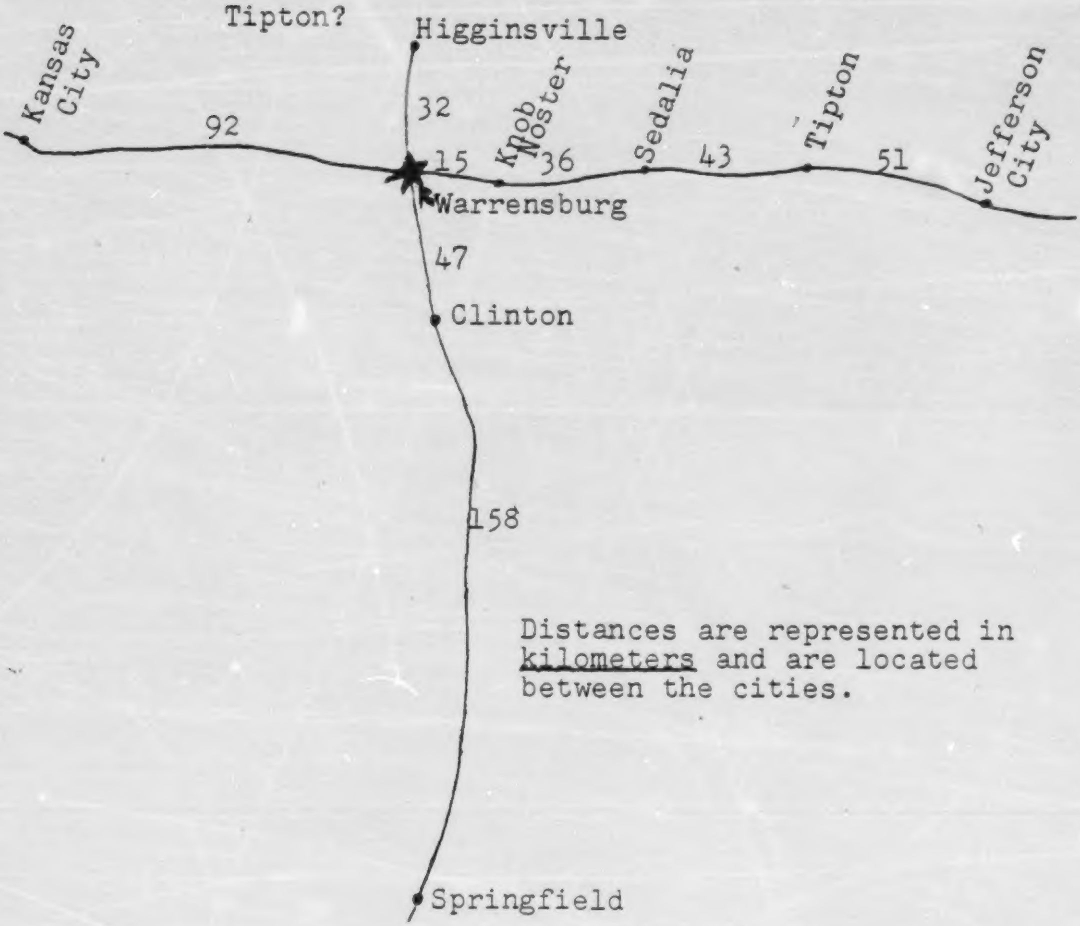
35. Warrensburg to Higginsville

36. Warrensburg to Sedalia

37. Warrensburg to Jefferson City

38. Is Warrensburg closer to Springfield or to Jefferson City?

39. Is Warrensburg closer to Kansas City or to Tipton?


Higginsville
Kansas City
92
32
15
Knob Noster
36
Sedalia
43
Tipton
51
Jefferson City
Warrensburg
47
Clinton
158
Springfield

Distances are represented in kilometers and are located between the cities.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Check all your answers with the KEY. You will find that the answers are not supplied for the Estimate questions. There are no wrong answers for the Estimate questions. However, notice the difference, if any, between your Estimated Measurement answers and the actual Measurement answers. This will help to show how well you understand SI Measurement.

Answer Sheet for

Lesson 3--Simulated Activity

Student # ________________ Teacher # ________________

SECTION #1--Time Started ________________

SECTION #2

1. Plastic strip "A" ________ (number) ________ (SI symbol)

2. Plastic strip "B" ________ (number) ________ (SI symbol)

3. Plastic strip "C" ________ (number) ________ (SI symbol)

SECTION #3

4. 5 m = ________ (number) dm

5. 10 m = ________ (number) dm

6. 13 m = ________ (number) dm

7. 30 dm = ________ (number) m

8. 70 dm = ________ (number) m

9. 140 dm = ________ (number) m

SECTION #4

10. Length ________ ________
(number) (SI symbol)

11. Width ________ ________
(number) (SI symbol)

SECTION #5

12. 1 dm = ________ cm
(number)

13. ________ cm = 5 dm
(number)

14. ________ cm = 10 dm
(number)

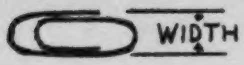
15. ________ m = 300 cm
(number)

16. ________ cm = 2 m
(number)

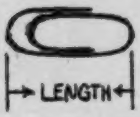
17. 400 cm = ________ m
(number)

SECTION #6

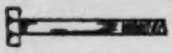
	ESTIMATE		MEASUREMENT
18.	________ ________ (number)(SI symbol)	←Compare→ Side A	21. ________ ________ (number)(SI symbol)
19.	________ ________ (number)(SI symbol)	←Compare→ Side B	22. ________ ________ (number)(SI symbol)
20.	________ ________ (number)(SI symbol)	←Compare→ Side C	23. ________ ________ (number)(SI symbol)

24. 

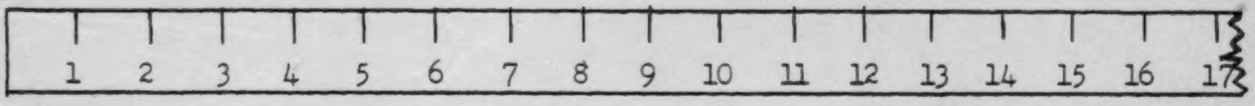
________ (number) ________ (SI symbol)

25. 

________ (number) ________ (SI symbol)

26. 
________ (number) ________ (SI symbol)

27.


1
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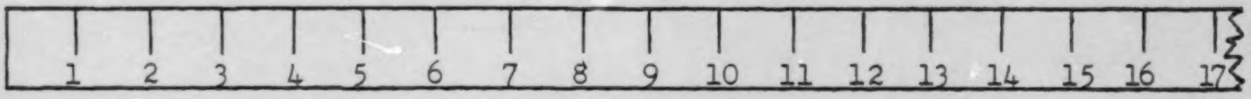
11
12
13
14
15
16
17

28.


1
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3
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6
7
8
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10
11
12
13
14
15
16
17

SECTION #7

29. 2 km = ________ (number) m

30. 32 km = ________ (number) m

31. 8 km = ________ (number) m

32. 4 000 m = ________ (number) km

33. 16 000 m = ________ (number) km

34. 9 000 m = ________ (number) km

*This page is reduced 15% from the original.

35. Warrensburg to Higginsville ________ (number) ________ (SI symbol)

36. Warrensburg to Sedalia ________ (number) ________ (SI symbol)

37. Warrensburg to Jefferson City ________ (number) ________ (SI symbol)

38. Warrensburg is closest to ________ (name of city), which is a distance of ________ (number) ________ (SI symbol).

39. The distance from Warrensburg to Kansas City is ________ (number) ________ (SI symbol) and the distance from Warrensburg to Tipton is ________ (number) ________ (SI symbol). Therefore, Warrensburg is closer to ________ (name of city) by a distance of ________ (number) ________ (SI symbol).

Time Completed ________

VOLUME/CAPACITY
IN
SI MEASUREMENT

Lesson 4

SIMULATED ACTIVITIES

General Directions

Please do not write in this booklet. A special answer sheet, which will be supplied by your teacher, will be used to record your answers. You will need to supply your own soft lead pencil.

You will be asked to record the time when you start an activity (Time Started) and the time when you complete an activity (Time Completed). Please take special care to record these times on your answer sheet.

Lesson 4

Volume/Capacity Measurement Activities

SECTION #1

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Volume or capacity is the amount of a substance or material that is held in or contained by a container. In other words, volume or capacity is the space inside a hollow object as well as the space which a solid object takes up. The volume or capacity of a container is measured in cubic units and the material to be measured may be a wet or liquid substance or it may also be a dry or solid material.

A cube is an object which has sides of equal length. In other words, a cube is a container where length = width = height. Here we have drawn a picture of a block or container that is a cube. This block or container has a volume or capacity of one cubic unit as shown in Figure #1.

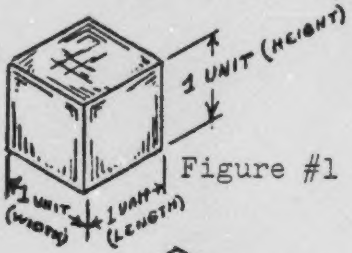


Figure #1

How many cubic units are needed to build the figure below in Figure #2?

There are two rows of blocks with 3 blocks in each row. We can therefore say that there are 2 x 3 or 6 cubic units in the figure.

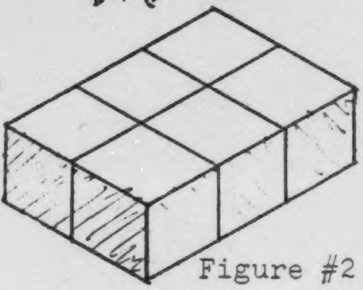
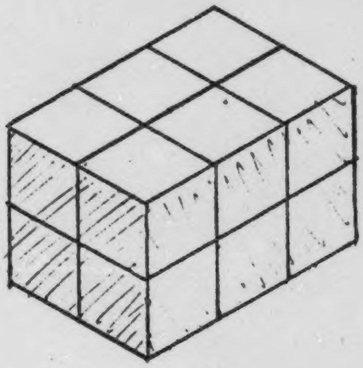


Figure #2

Now let's lay another layer of cubes on the top of the figure which we just examined. How many cubic units are needed for this new figure?

We again have two rows of blocks with three blocks in each row, which makes a total of 2 x 3 or 6 cubic units for the first layer. However, since there are two layers with 6 cubic units in each layer, we now have a volume of 12 cubic units (6 units x 2 layers) in the new figure which appears to the right.

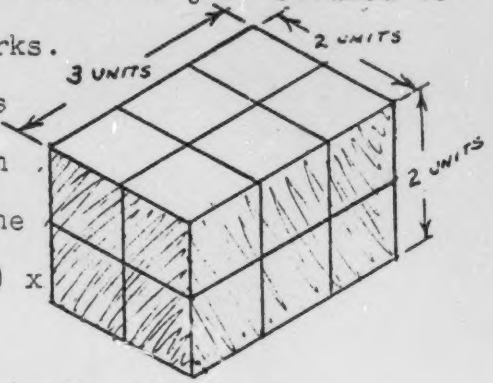


There is still a simpler way to figure the volume of an object. You can find the volume of something by using the following formula:

Volume = length x width x height
(This can be abbreviated as follows)
V = L x W x H

Let's use the same problem which we just studied to see how the formula for volume works.

To find the volume of this figure, use the formula above. In other words, volume is equal to the length (3 units) x width (2 units) x height (2 units).



Volume = 3 units x 2 units x 2 units

or Volume = 12 cubic units.

Therefore the volume or capacity of the figure on the preceding page would have been written 12 units^3 (read "cubic units"). The small "3" which is placed above and to the right of the word "unit" is used to show that a volume measure has been made. In other words, when we multiply the length x width x height of an object we get the volume or capacity of the object which is given in units cubed. This is written "units^3".

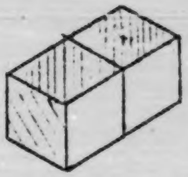
PRACTICE PROBLEMS:

Please figure the volume or capacity of each of the objects shown below. Write your answer on the answer sheet beside the corresponding item number.

Formula for Volume

Volume = length x width x height

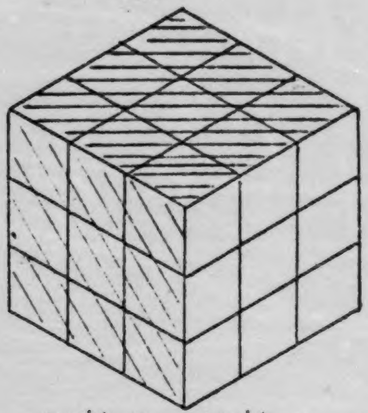
1.



V = __unit x __unit x __unit

V = ____________units^3

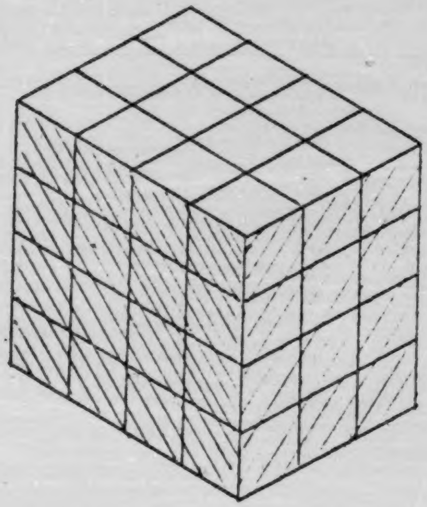
2.



V = __unit x __unit x __unit

V = ____________units^3

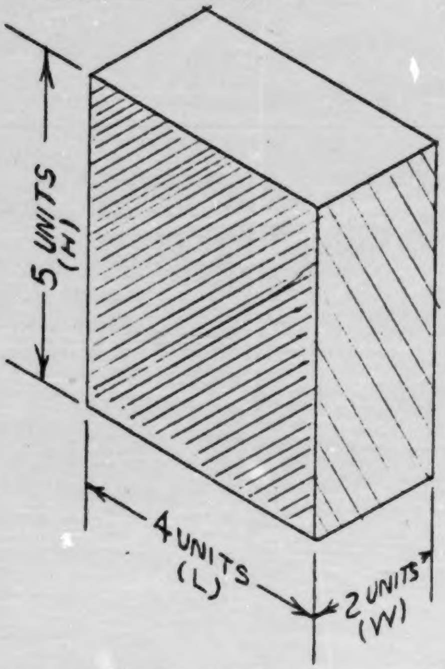
3.



V = __unit x __unit x __unit

V = ____________units^3

4.

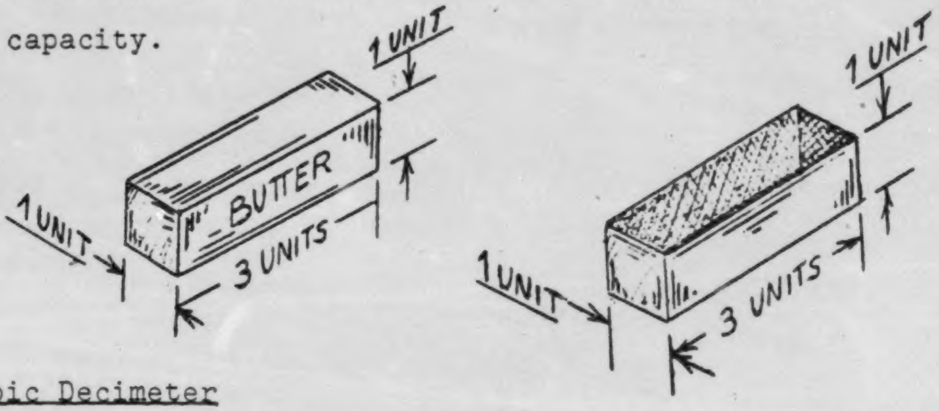


V = __unit x __unit x __unit

V = ____________units^3

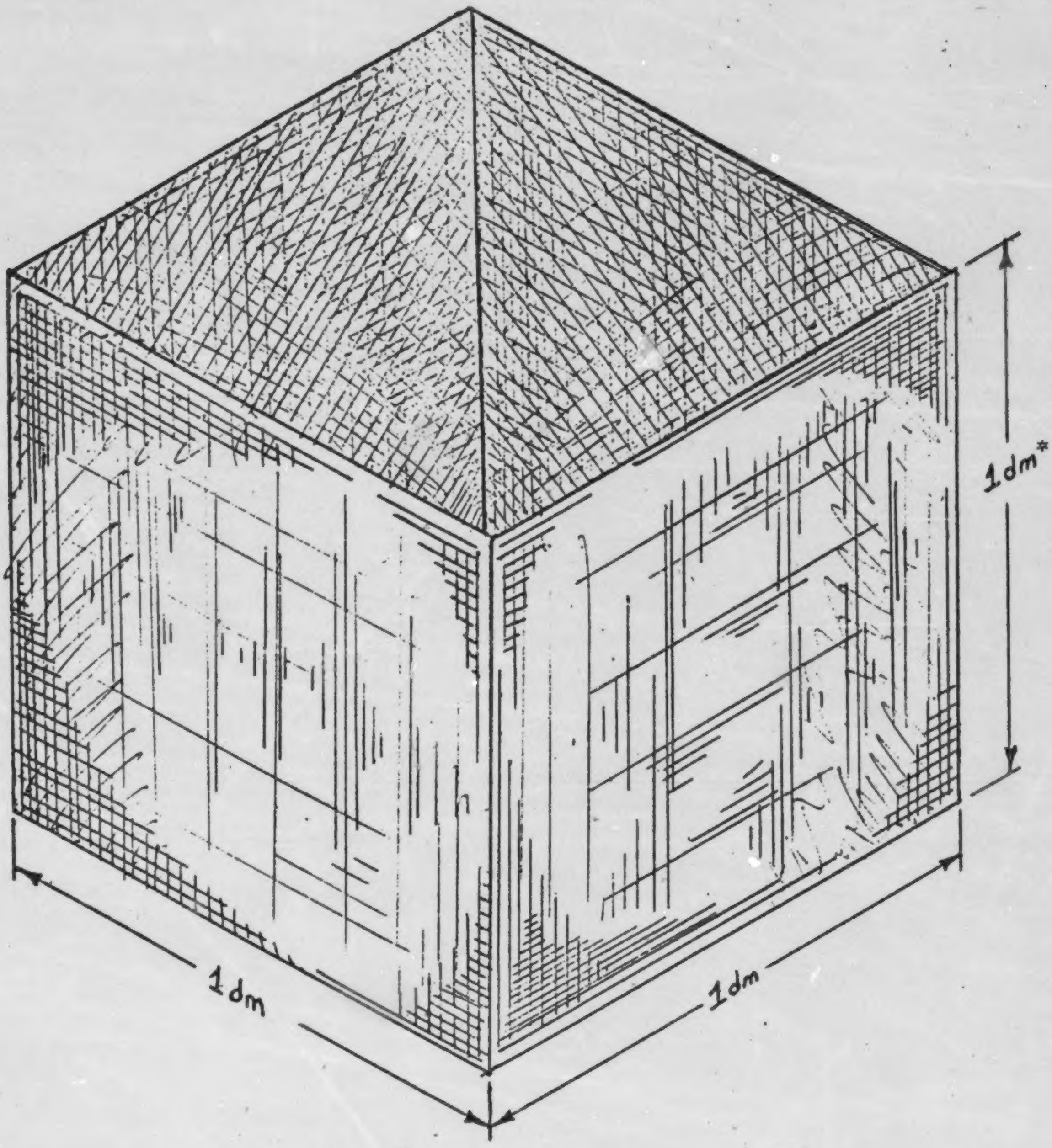
Key Point The volume or capacity of solid objects as well as empty boxes or containers is figured in cubic units.

The examples below show that a piece of butter and an empty box with the same dimensions have the same volume or capacity.



Cubic Decimeter

We have been studying about the volume or capacity of objects which are measured in cubic units. One of the SI units which is used to measure volume or capacity is the cubic decimeter. The SI symbol for the cubic decimeter is "dm^3". It is a cube where the length of each side is 1 decimeter (dm). We can therefore say that it has a capacity or volume of 1 dm^3. The figure on the next page represents a true volume of one cubic decimeter (dm^3).



*This page is reduced 23% from the original.

Your teacher will hold up a cube that also has a volume of one cubic decimeter (dm^3). A cubic decimeter is about the same size as the bottom half of a half-gallon milk carton and therefore has the same volume or capacity.

SECTION #2

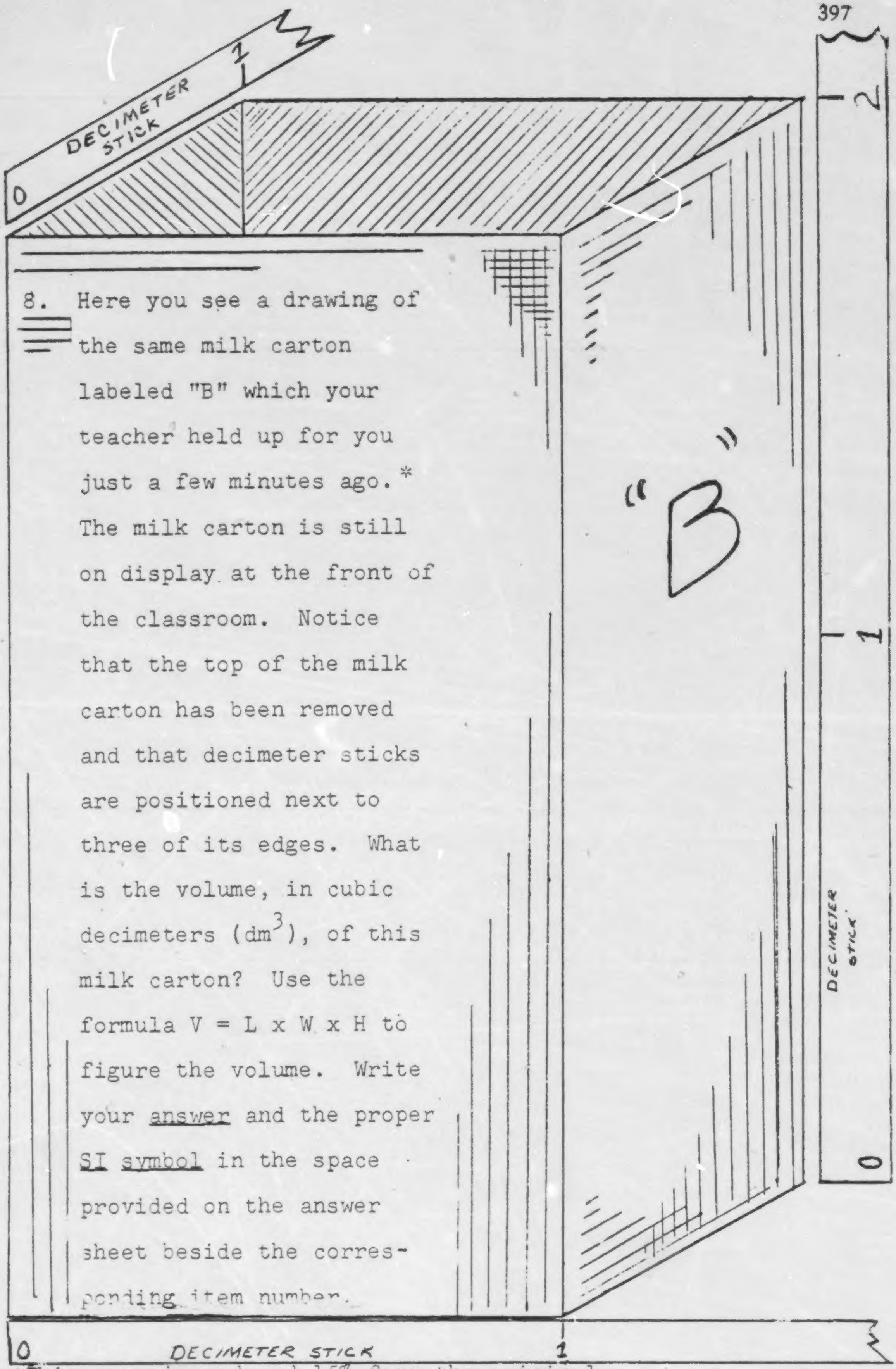
Simulated Activities:

5. Look to the front of the classroom. Your teacher will be holding an empty milk carton labeled "B" with its top removed. You are to estimate the volume of the milk carton in cubic decimeters (dm^3), ($V = L \times W \times H$). Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.

6. Look to the front of the classroom. Your teacher will be holding a foam rubber block labeled "C". You are to estimate the volume of the block in cubic decimeters (dm^3), ($V = L \times W \times H$). Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.

7. Look again to the front of the classroom. This time your teacher will be holding an empty box. You are to estimate its volume in cubic decimeters (dm^3), ($V = L \times W \times H$). Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.

8. Here you see a drawing of the same milk carton labeled "B" which your teacher held up for you just a few minutes ago.* The milk carton is still on display at the front of the classroom. Notice that the top of the milk carton has been removed and that decimeter sticks are positioned next to three of its edges. What is the volume, in cubic decimeters (dm^3), of this milk carton? Use the formula $V = L \times W \times H$ to figure the volume. Write your answer and the proper SI symbol in the space provided on the answer sheet beside the corresponding item number.



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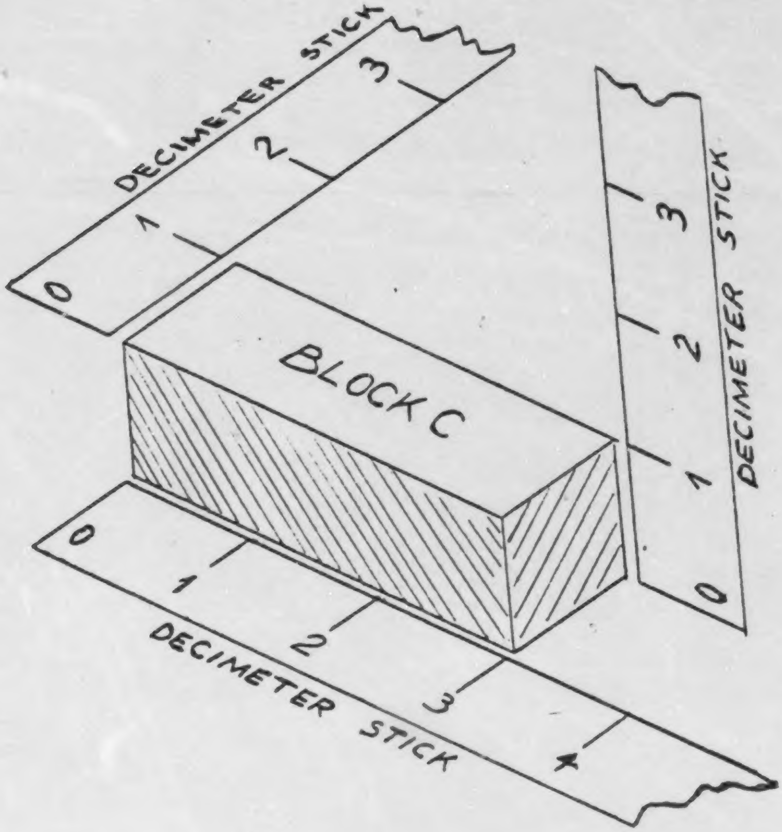
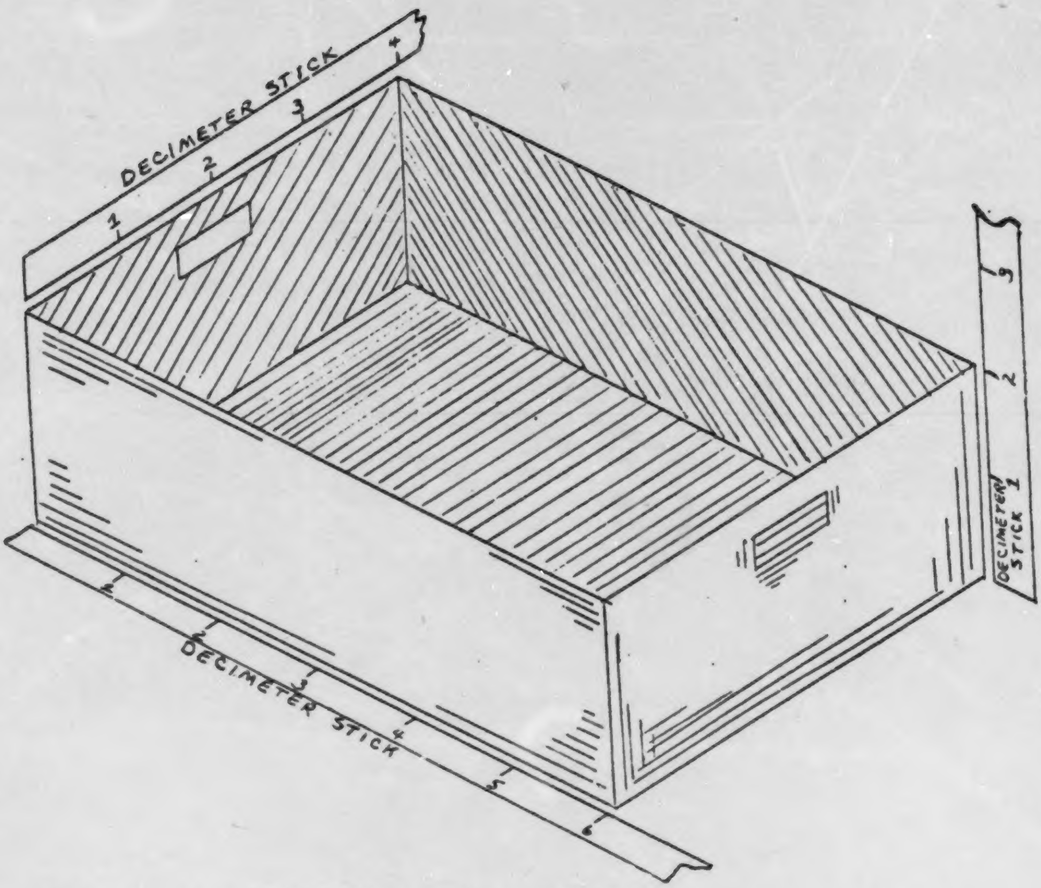
*This page is reduced 15% from the original.

Below you see a drawing of the same foam rubber block which your teacher held up for you just a few minutes ago. The block is still on display at the front of the classroom. Please notice that both the drawing below along with the decimeter sticks which appear around the block are drawn one-fifth their actual size.

9. Find the volume, in cubic decimeters (dm^3), of the foam rubber block labeled "C" pictured below. Use the formula V = L x W x H to figure the volume. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.


DECIMETER STICK
0
1
2
3
BLOCK C
DECIMETER STICK
0
1
2
3
DECIMETER STICK
0
1
2
3
4

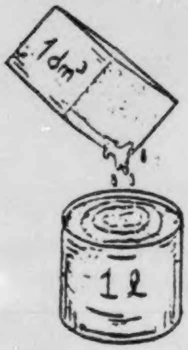
10. Find the volume, in cubic decimeters (dm^3), of the box pictured below. This box, like the drawing of the foam rubber block, is drawn to one-fifth of its actual size. This drawing is used to represent the same large box which your teacher showed you a few minutes ago. The box is still on display at the front of the room. Use the formula V = L x W x H to figure the volume. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.


DECIMETER STICK
1
2
3
4
DECIMETER STICK
1
2
3
DECIMETER STICK
1
2
3
4
5
6

*This page is reduced 23% from the original.

SECTION #3

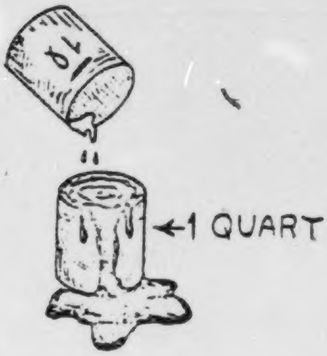
Earlier in this lesson it was mentioned that the volume or capacity of a liquid can also be measured. Thus far we have only discussed cubic units and in particular the cubic decimeter which was used to measure the volume or capacity of solid objects and empty containers. It so happens that there is a relationship between the cubic units, which we have discussed, and liquid units. For example, the volume or capacity of 1 cubic decimeter is 1 liter. The liter is the basic unit of capacity. The symbol for liter is the small letter "l". The small letter "l" is also made in the cursive form which is "ℓ" so that it will not be confused with the number 1.



Key Point

l = 1 dm^3

One liter is slightly more than a quart.



In SI Measurement, we measure liquid substances such as milk and gas by the liter (ℓ). Liquids are measured with the aid of graduates, beakers, cylinders, etc. Your teacher will show you an example of a liter measure at a later time during this lesson.

PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item number.

11. $1\ \text{dm}^3 = \underset{\text{(number)}}{\underline{\quad ? \quad}}\ \ell$

12. $3\ \text{dm}^3 = \underset{\text{(number)}}{\underline{\quad ? \quad}}\ \ell$

13. $\underset{\text{(number)}}{\underline{\quad ? \quad}}\ \text{dm}^3 = 15\ \ell$

14. $\underset{\text{(number)}}{\underline{\quad ? \quad}}\ \text{dm}^3 = 9\ \ell$

15. $7\ \text{dm}^3 = \underset{\text{(number)}}{\underline{\quad ? \quad}}\ \underset{\text{(SI symbol)}}{\underline{\quad ? \quad}}$

16. $\underset{\text{(number)}}{\underline{\quad ? \quad}}\ \underset{\text{(SI symbol)}}{\underline{\quad ? \quad}} = 12\ \ell$

SECTION #4

Simulated Activities:

17. Look to the front of the classroom. Your teacher will be holding a coffee can labeled "D". You are to estimate the liter (ℓ) capacity of the coffee can. Write your *answer* along with the proper *SI symbol* on the answer sheet beside the corresponding item number.

18. Look to the front of the classroom. Your teacher will be holding an empty milk carton labeled "B" with its top removed. You are to estimate the liter (ℓ) capacity of milk carton "B". Write your *answer* along with the proper *SI symbol* on the answer sheet beside the corresponding item number.

NOTE: In the activities that follow we would like for you to pretend that the sand which you will be using is water. It was felt that water would create more of a mess than would sand.

19. Look to the front of the classroom. Your teacher will be displaying the empty coffee can labeled "D" and the liter measure pictured on the following page. The pictures on the following page show the liter measure and coffee can at one-tenth their actual size. The coffee

can, filled with sand, is being emptied into the liter measure in Step #2. You are to determine the liter (ℓ) capacity of the coffee can. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.

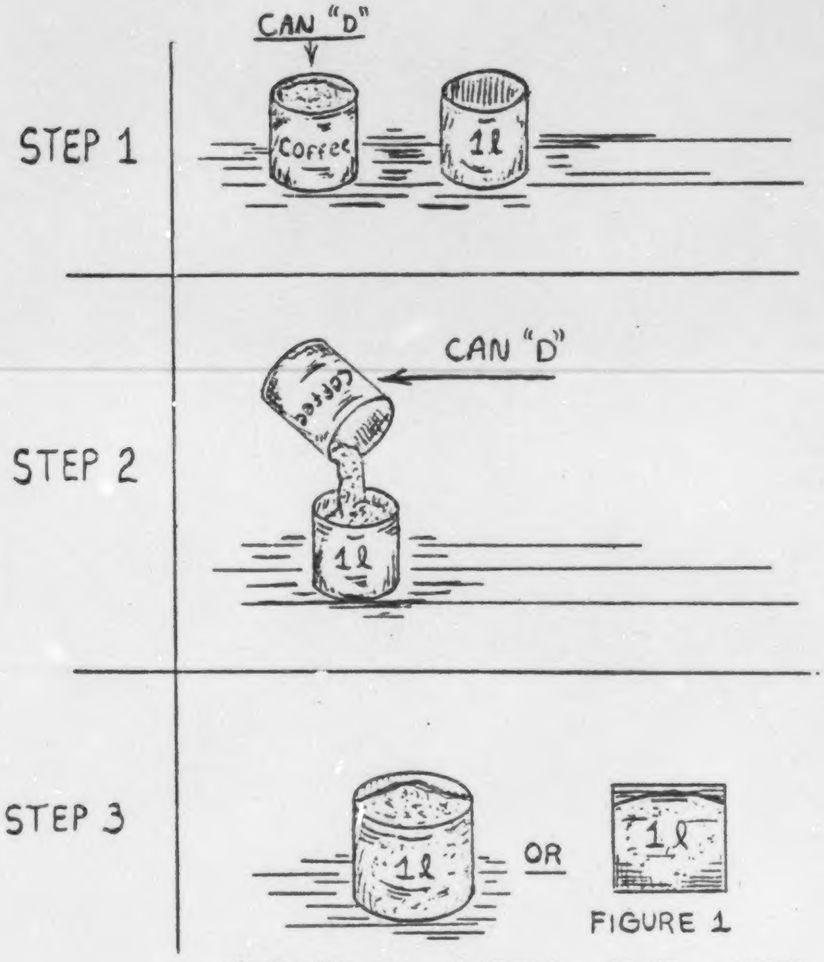
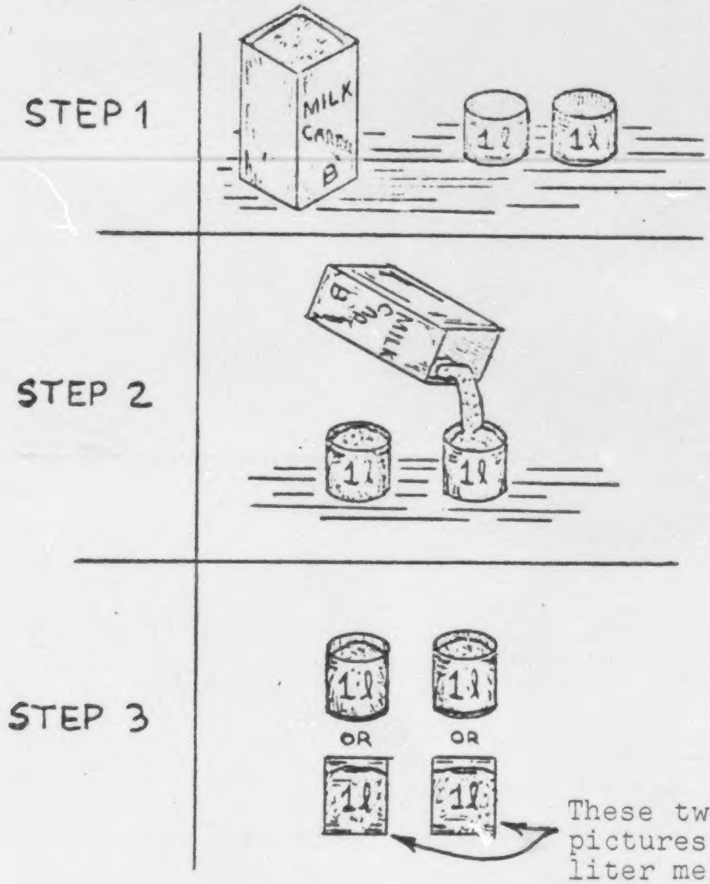

CAN "D"
STEP 1
Coffee
1ℓ
CAN "D"
STEP 2
Coffee
1ℓ
STEP 3
1ℓ
OR
1ℓ
FIGURE 1

FIGURE #1 SHOWS THE LITER MEASURE WHEN IT IS LEVEL.

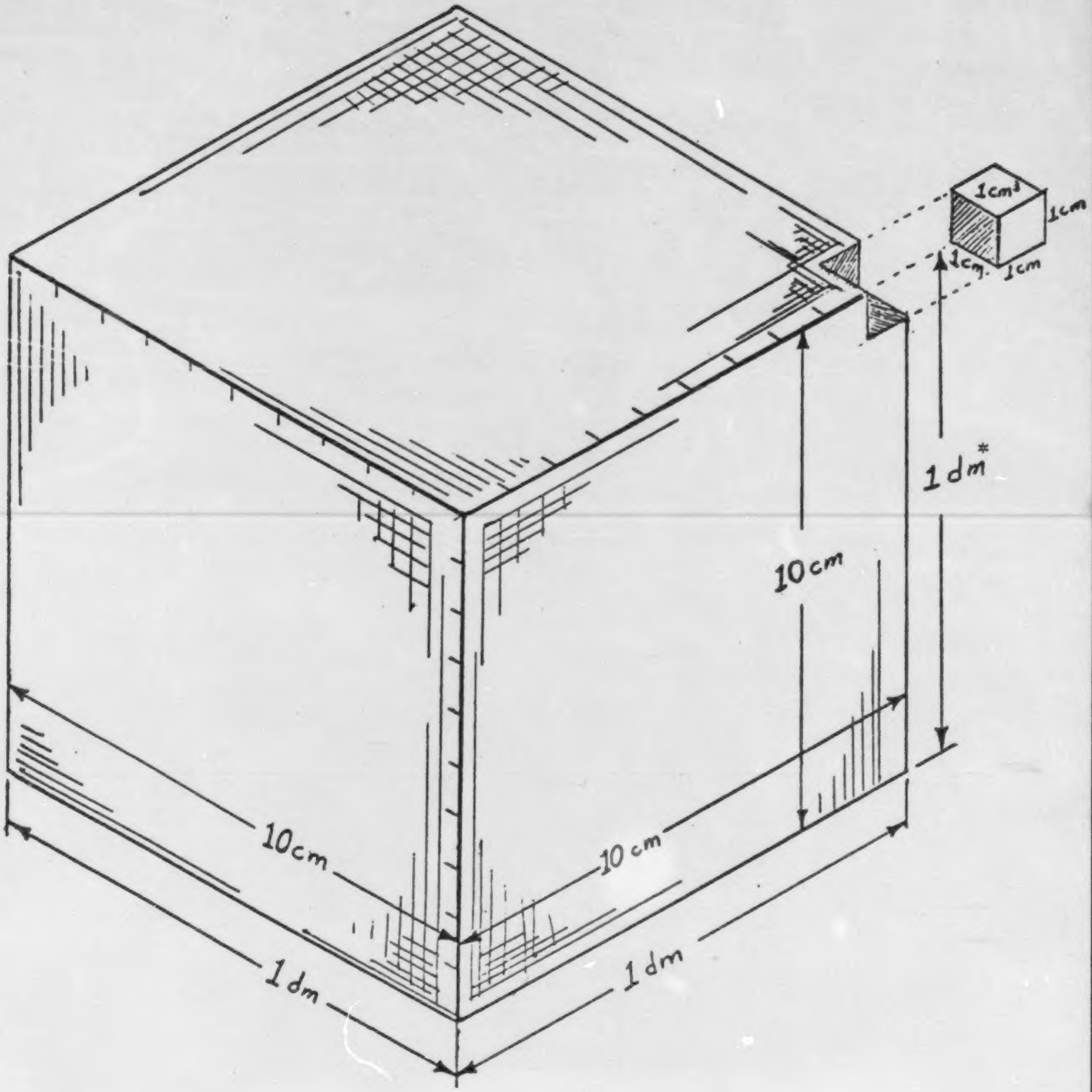
20. Look again to the front of the classroom. Your teacher will be displaying the milk carton labeled "B" which has the top removed and the liter measure. Both of these are drawn below to one-tenth of their actual size. The milk carton, filled with sand is being emptied into the liter measure in Step 2. You are to determine the liter (ℓ) capacity of the milk carton. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.


STEP 1
MILK CARTON
B
1ℓ
1ℓ
STEP 2
B
CARTON
MILK
1ℓ
1ℓ
STEP 3
1ℓ
1ℓ
OR
OR
1ℓ
1ℓ

These two pictures show the liter measures when they are level.

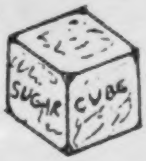
SECTION #5

A cubic centimeter is a unit of volume that is used to make smaller measures. The symbol for cubic centimeter may be written as "cm^3". Notice in the figure on the following page the actual size of a cubic centimeter (cm^3) and its relationship to the cubic decimeter.


1cm³
1cm
1cm.
1cm
1 dm*
10 cm
10cm
10 cm
1dm
1dm

*This page is reduced 38.5% from the original.

A sugar cube is a little larger in size than a cubic centimeter.



Do you know how many cubic centimeters there are in a cubic decimeter? Let's review and find out.

Key Point

Remember that the volume can be found by using the formula: Volume = Length x Width x Height which is abbreviated V = L x W x H.

Therefore if we substitute the number of centimeters that are in a decimeter (10 centimeters = 1 decimeter) for each of the three dimensions, we find that:

$$\text{Volume of } 1\ dm^3 = 10\ cm \times 10\ cm \times 10\ cm$$

(therefore)

$$\text{Volume of } 1\ dm^3 = 1\ 000\ cm^3$$

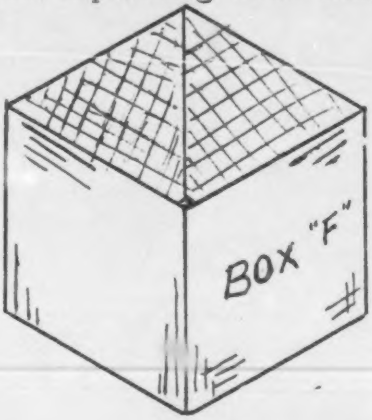
Key Point $1\ dm^3 = 1\ 000\ cm^3$ $1\ cm^3 = .001\ dm^3$

From the above problem we can see that it would take approximately 1,000 sugar cubes to fill the cubic decimeter container shown on the preceding page.

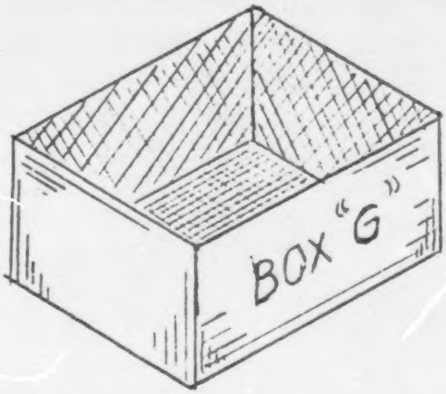
SECTION #6

Simulated Activities:

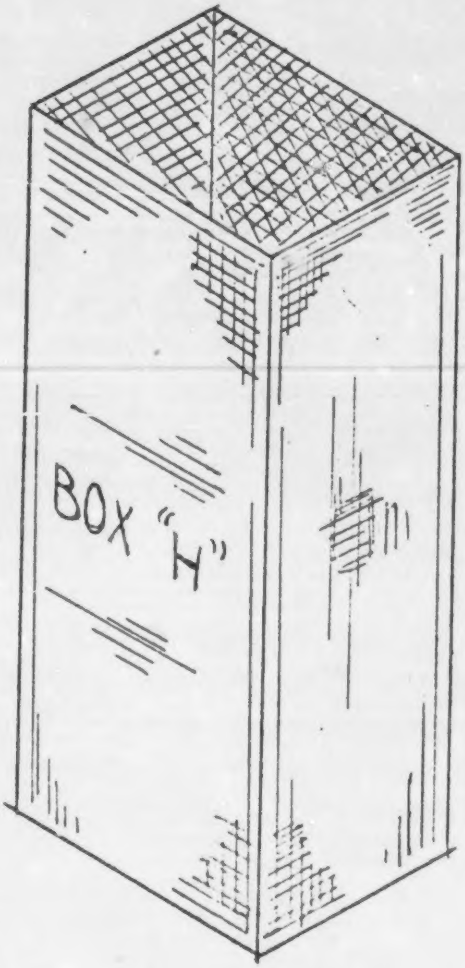
21. Estimate the volume, in cubic centimeters (cm^3), of box "F" which is drawn full size using the formula V = L x W x H. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



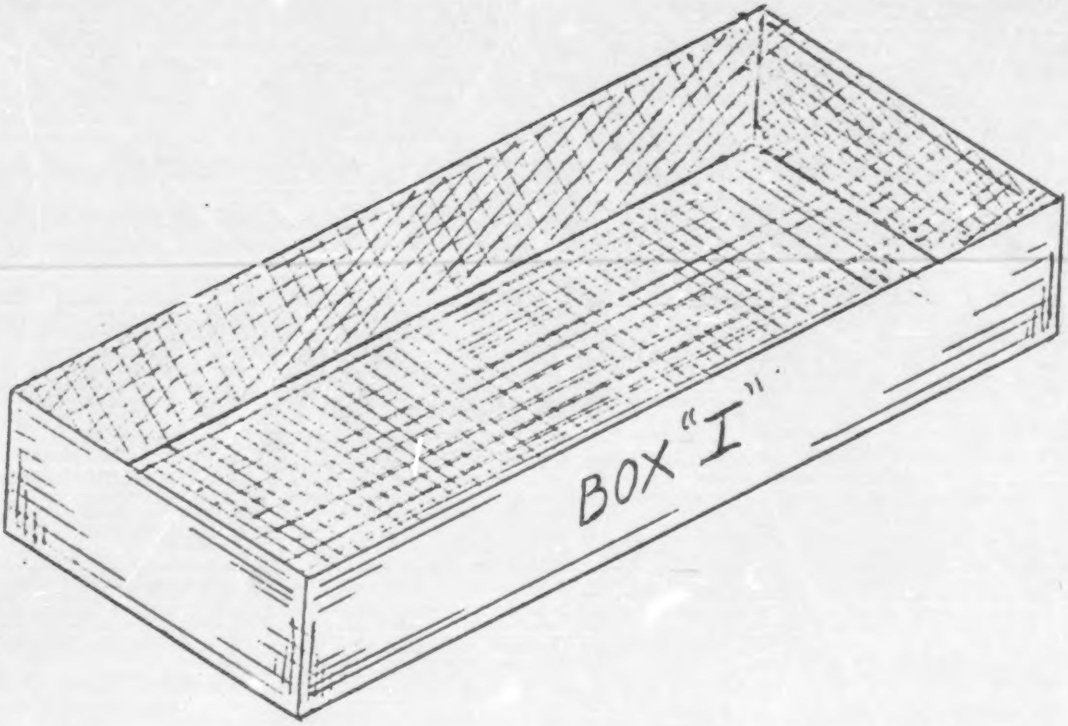
22. Estimate the volume, in cubic centimeters (cm^3), of box "G" which is drawn full size, using the formula V = L x W x H. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



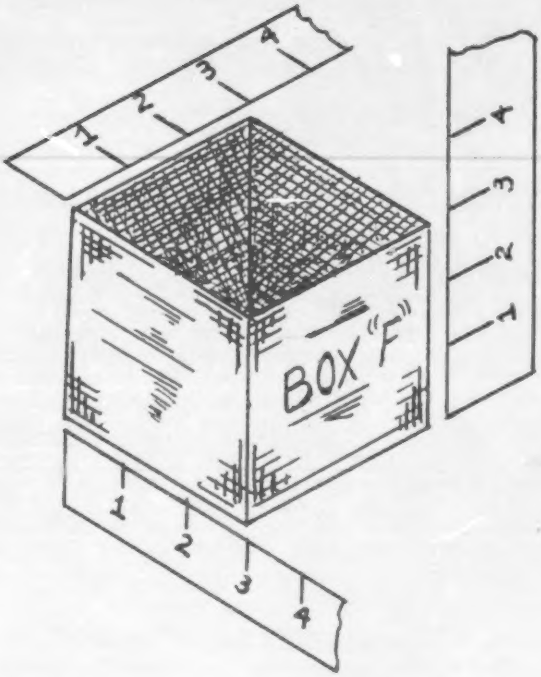
23. Estimate the volume, in cubic centimeters (cm^3), of box "H" which is drawn full size, using the formula V = L x W x H. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



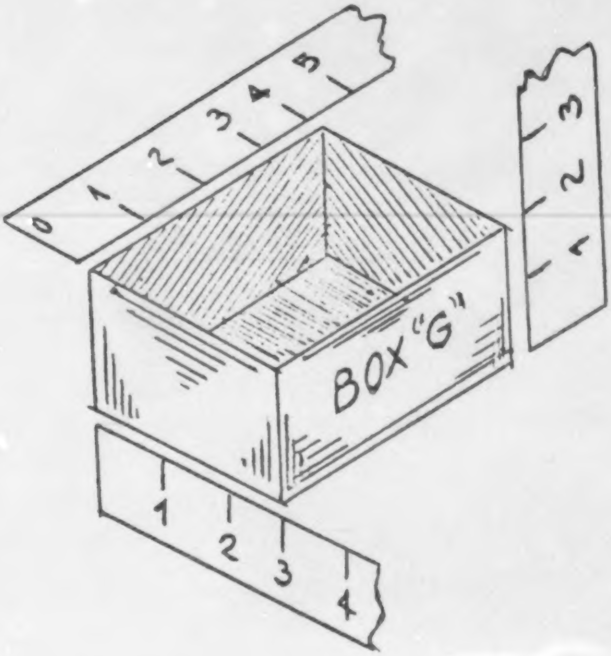
24. Estimate the volume, in cubic centimeters (cm^3), of box "I", which is drawn full size, using the formula V = L x W x H. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



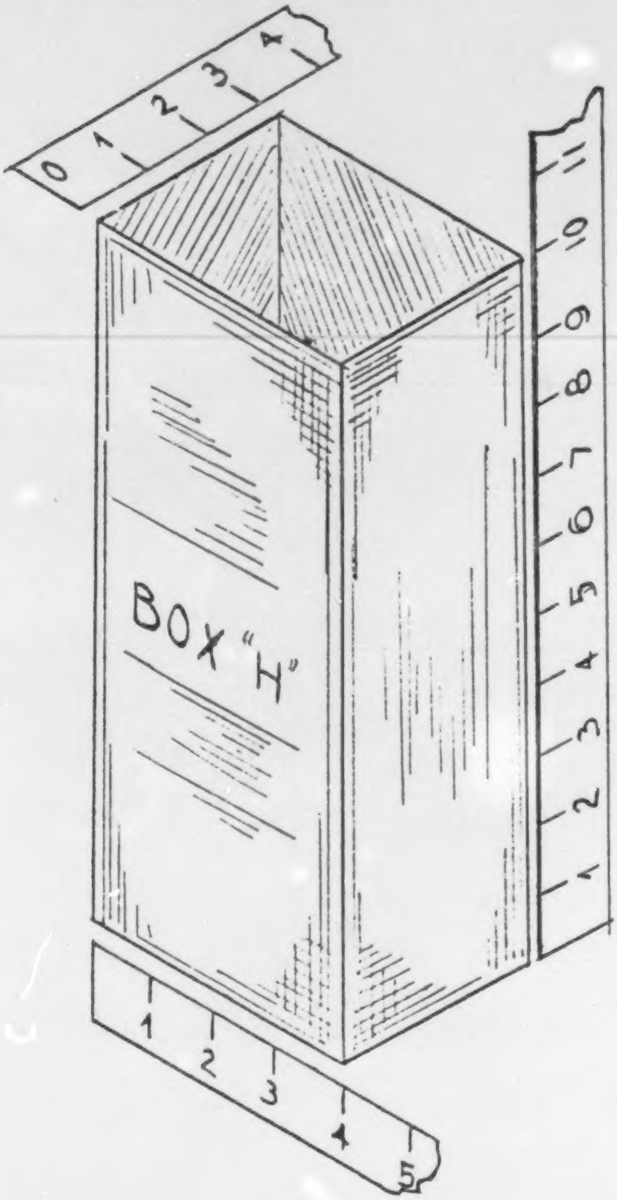
25. Find the volume, in cubic centimeters (cm^3), of box "F" which is drawn full size. Use the centimeter sticks pictured next to each box and use the formula V = L x W x H to arrive at your answer. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



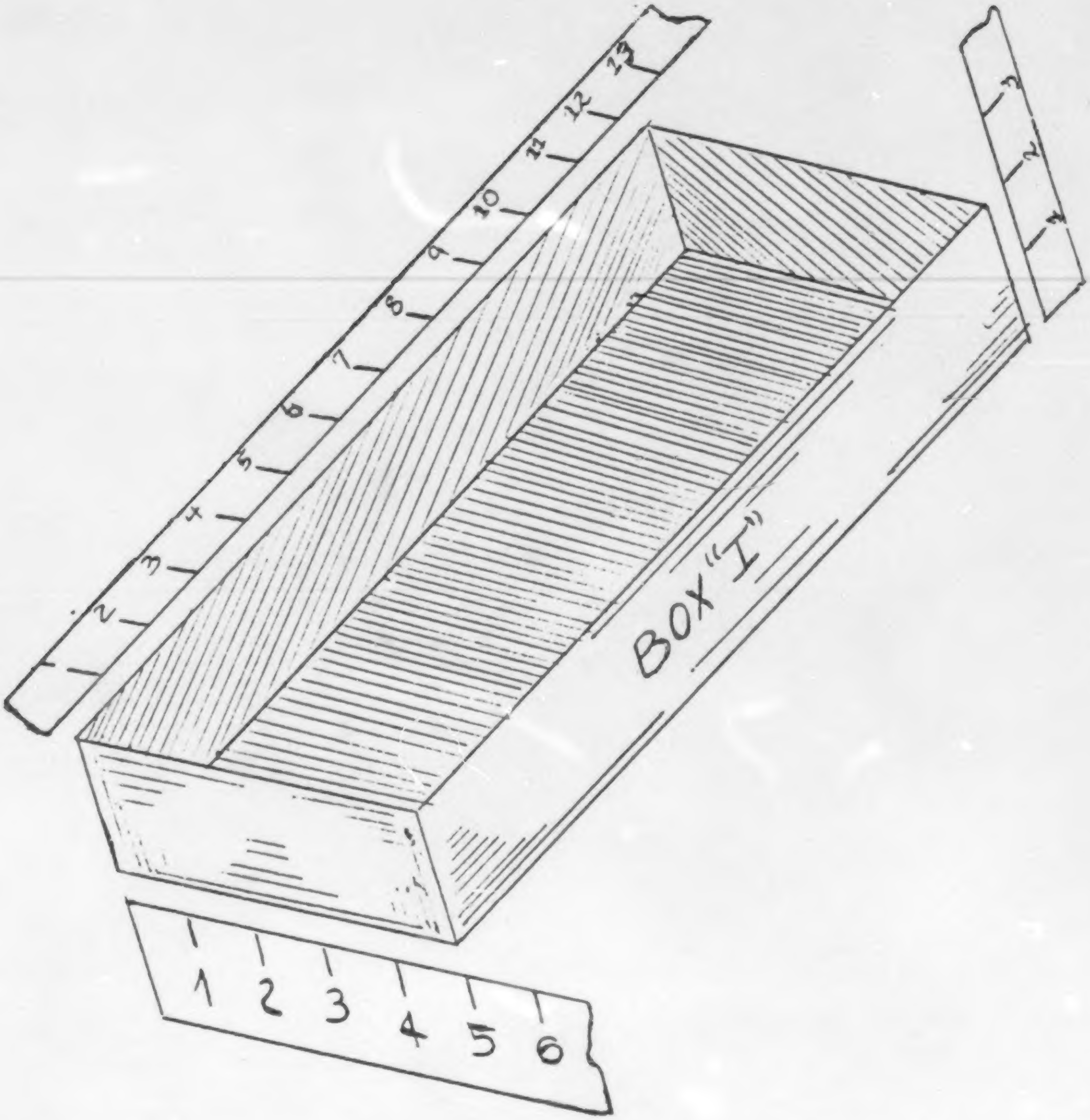
26. Find the volume, in cubic centimeters (cm^3), of box "G" which is drawn full size. Use the centimeter sticks pictured next to each box and use the formula V = L x W x H to arrive at your answer. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



27. Find the volume, in cubic centimeters (cm^3), of box "H" which is drawn full size. Use the centimeter sticks pictured next to each box and use the formula V = L x W x H to arrive at your answer. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.


0
1
2
3
4
BOX "H"
1
2
3
4
5
6
7
8
9
10
11
1
2
3
4
5

28. Find the volume, in cubic centimeters (cm^3), of box "I" which is drawn full size. Use the centimeter sticks pictured next to each box and use the formula V = L x W x H to arrive at your answer. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.


2
3
4
5
6
7
8
9
10
11
12
13
1
2
3
BOX "I"
1
2
3
4
5
6

SECTION #7

Milliliter

It was mentioned earlier that the capacity of one cubic decimeter (1 dm^3) is equal to one liter (1 ℓ). The same relationship exists between the cubic centimeter and the milliliter. The prefix milli is used to represent one-thousandth of something. The capacity of one cubic centimeter (1 cm^3) is equal to one milliliter (1 mℓ). The symbol for milliliter is the small letters "mℓ".

Key Point 1 [illegible]m^3 = 1 mℓ

This re[illegible]ip is best explained by recalling a few **key points**:

1. You will recall that the prefix milli is used to represent one-thousandth. Therefore, we can assume that a milliliter (mℓ) is 1 of 1 000 parts of a liter.

   Key Point milli = one thousandth

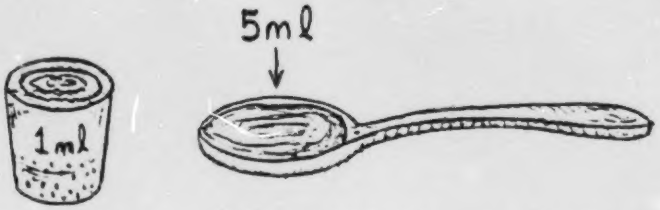
2. You were also told that *each cubic centimeter* is 1 of 1 000 parts of a cubic decimeter.

   Key Point 1 dm^3 = 1 000 cm^3

3. Therefore since you were told that one *cubic* decimeter (1 dm^3) has a capacity of one liter (1 ℓ), then one cubic centimeter has a capacity of one milliliter (1 mℓ).

   Key Point 1 dm^3 = 1ℓ and 1 cm^3 = 1 mℓ

A thimble will hold about one milliliter (mℓ) of water while a teaspoon will hold about 5 milliliters (mℓ) of water.



Very small amounts of liquids like medicines are measured in milliliters (mℓ). Your teacher will show you a graduate which can be used to very accurately measure small amounts of liquids.

PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write the answer for each question on the answer sheet beside the corresponding item number.

29. 1 mℓ = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ cm^3

30. 2 000 cm^3 = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ ℓ

31. 5 000 mℓ = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ ℓ

32. 2 000 cm^3 = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ dm^3

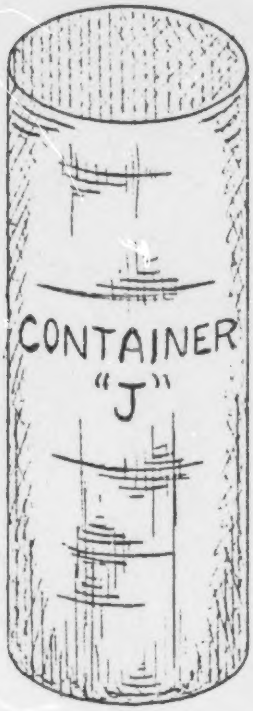
33. $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ mℓ = 9 ℓ

34. 18 000 cm^3 = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ ℓ

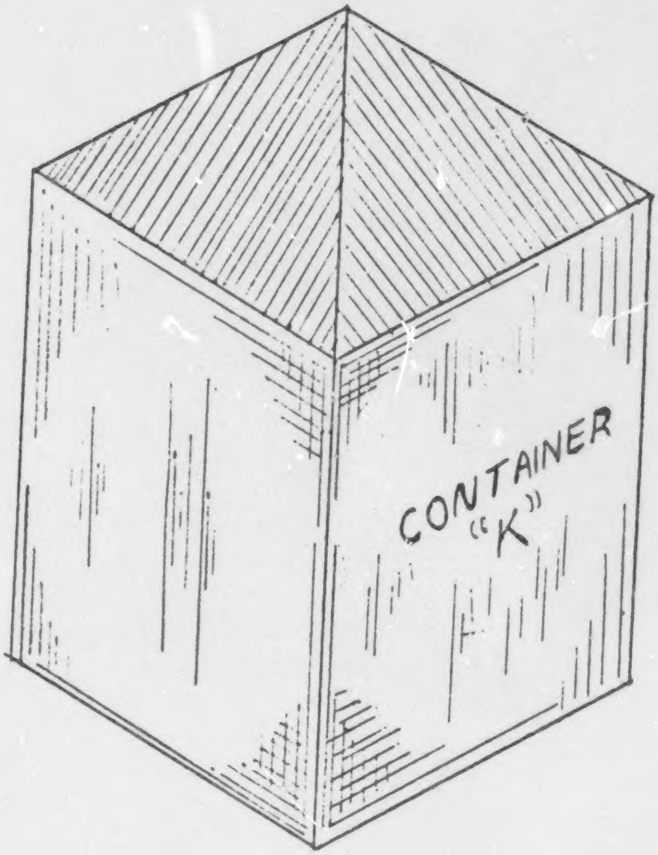
SECTION #8

Simulated Activities:

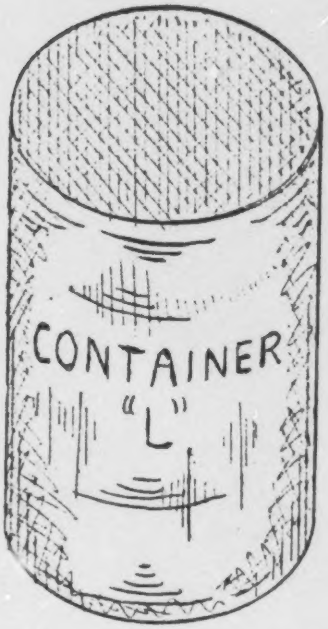
35. Estimate the capacity, in milliliters (mℓ), of container "J" which is drawn full size, using the formula V = L x W x H. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



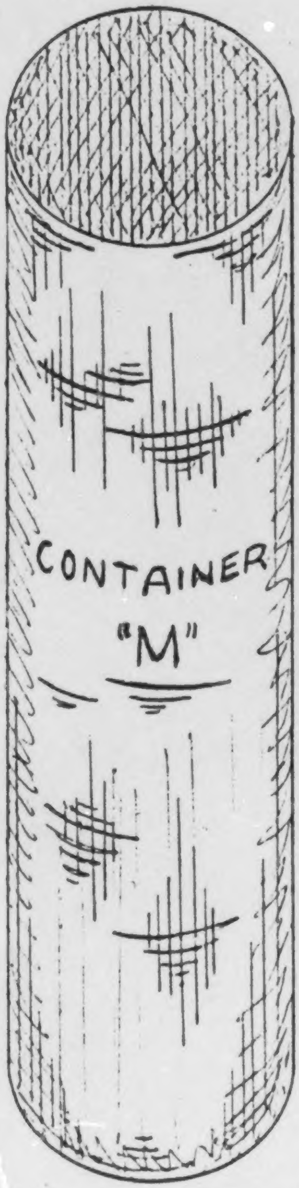
36. Estimate the capacity, in milliliters (mℓ), of container "K" which is drawn full size using the formula V = L x W x H. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.



37. Estimate the capacity, in milliliters (mℓ), of container "L" which is drawn full size using the formula V = L x W x H. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

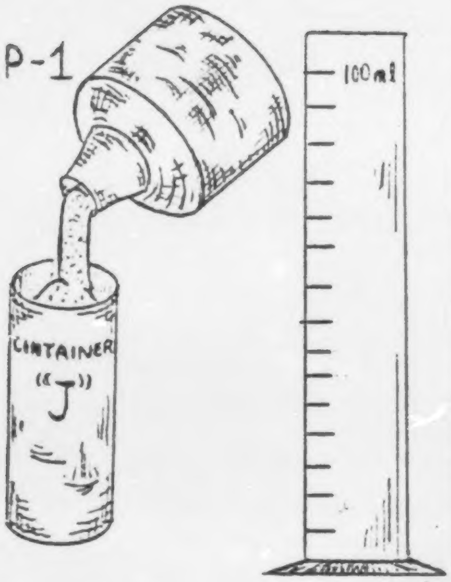


38. Estimate the capacity, in milliliters (mℓ), of container "M" which is drawn full size using the formula V = L x W x H. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

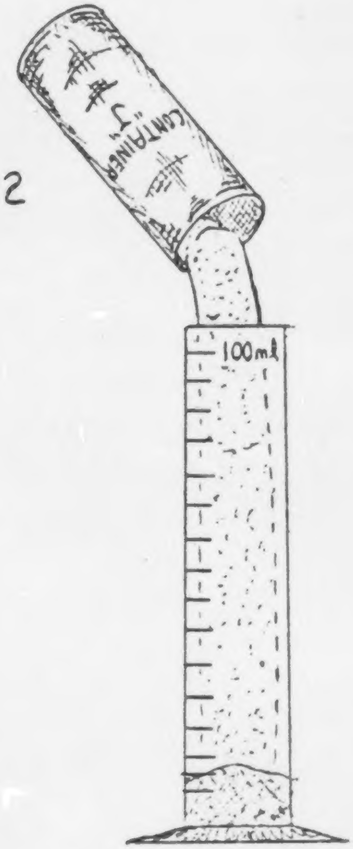


39. CONTAINER "J"--Look to the front of the classroom. Your teacher will be holding container "J" and a 100 milliliter graduate. The 100 milliliter graduate is drawn full size in the picture on the right side of the next page. The drawings on the left side of the next page show container "J" drawn to scale as well as being filled with sand and then being emptied into the 100 milliliter graduate. Determine the capacity of container "J" by reading the scale of the full size graduate shown in Step 3. The shaded portion of the graduate in Step 3 represents the sand on the inside. Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

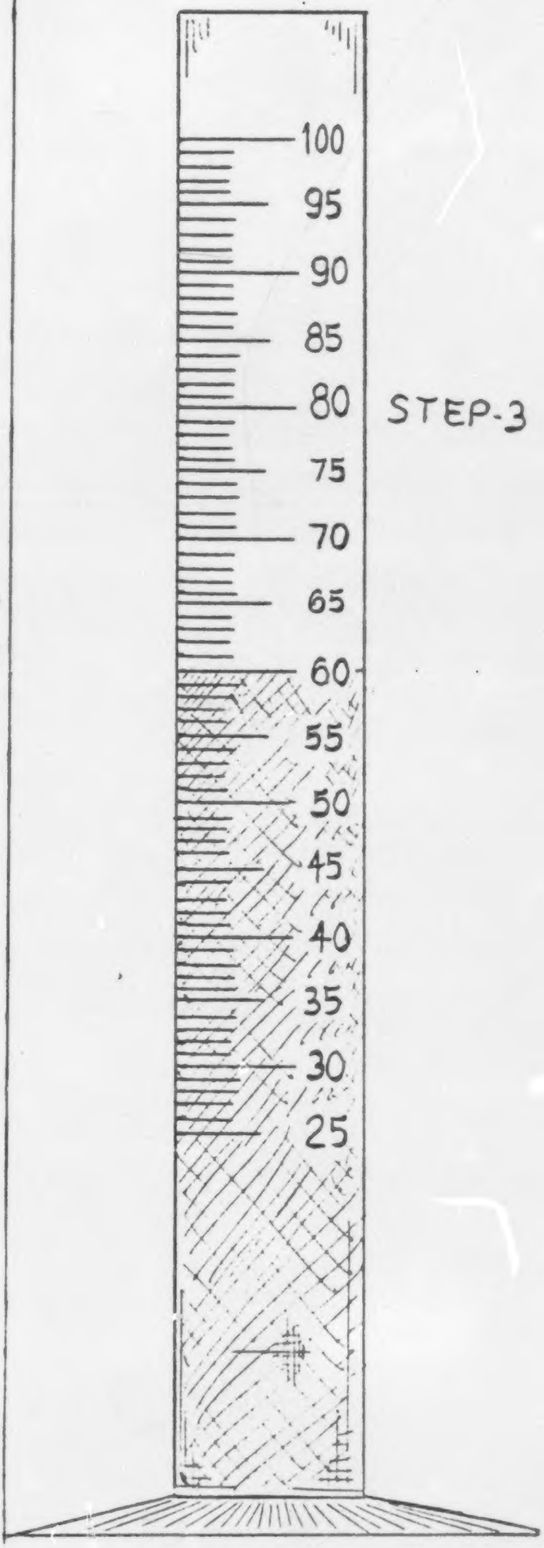
STEP-1


CONTAINER
"J"
100 ml

STEP-2

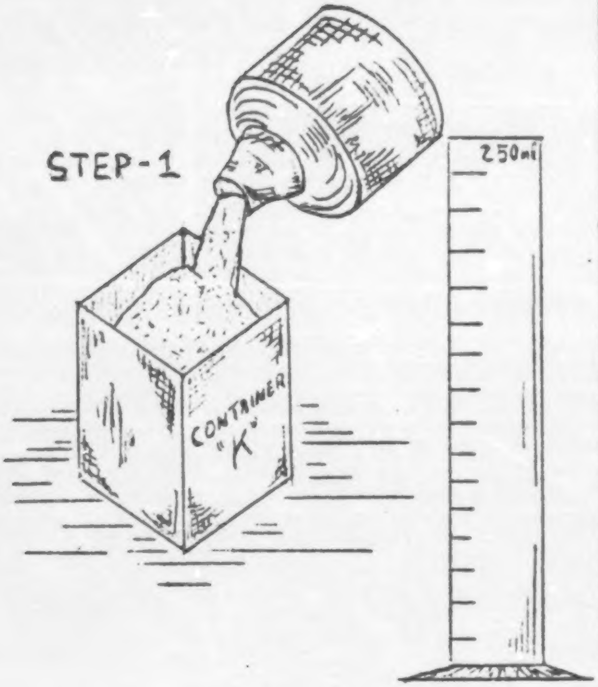

CONTAINER
"J"
100 ml

STEP-3

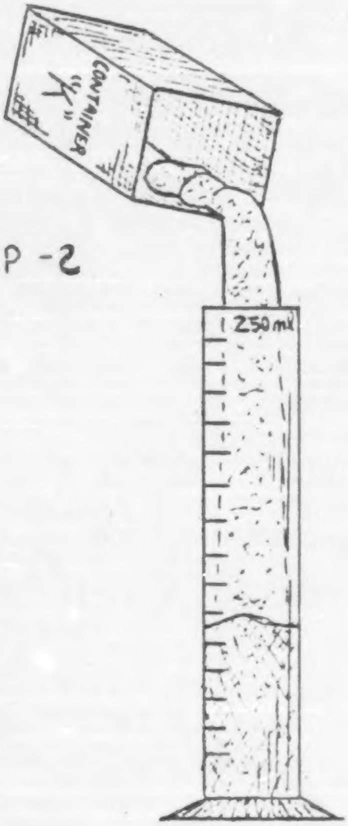

100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25

40. CONTAINER "K"--Look to the front of the classroom. Your teacher will be holding container "K" and a 250 milliliter graduate. The 250 milliliter graduate is drawn to scale in the picture on the right side of the next page. The drawings on the left side of the next page show container "K" drawn to scale as well as being filled with sand and then being emptied into the 250 milliliter graduate. Determine the capacity of container "K" by reading the scale of the graduate shown in Step 3. The shaded portion of the graduate in Step 3 represents the sand on the inside. Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

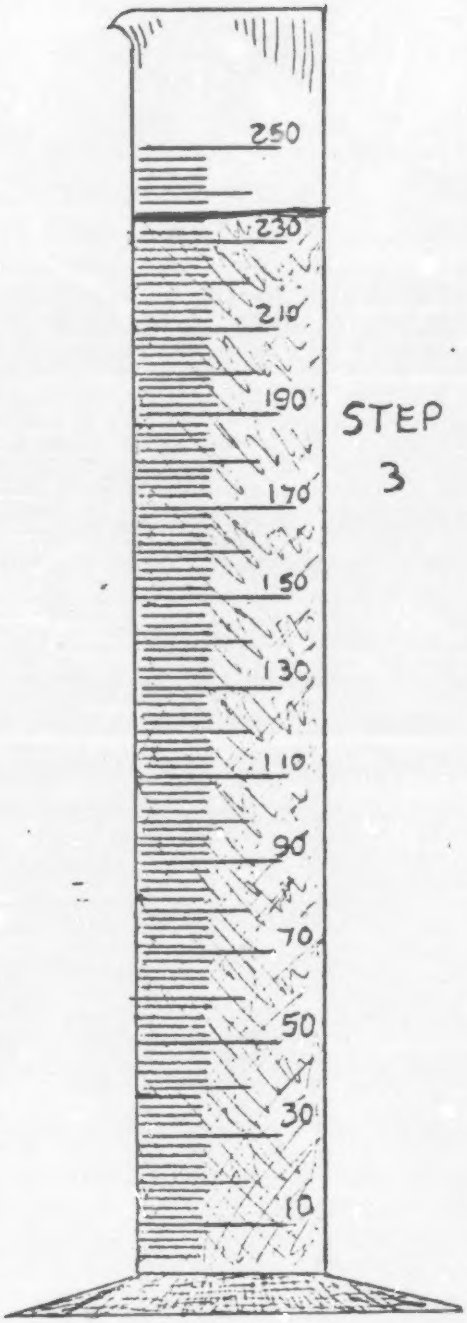
STEP-1


250ml
CONTAINER
"K"

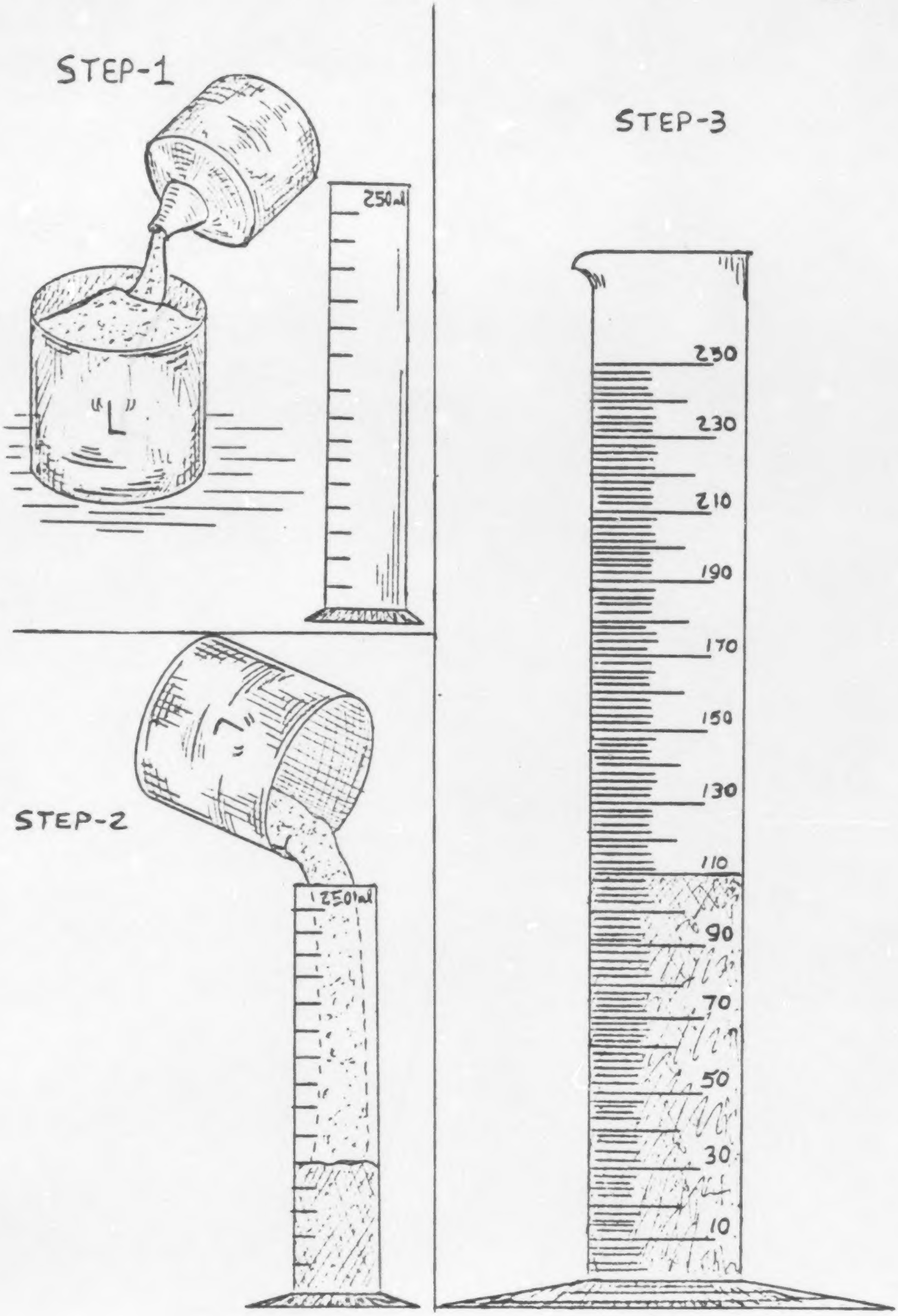
STEP-2


CONTAINER
"K"
250ml

STEP 3

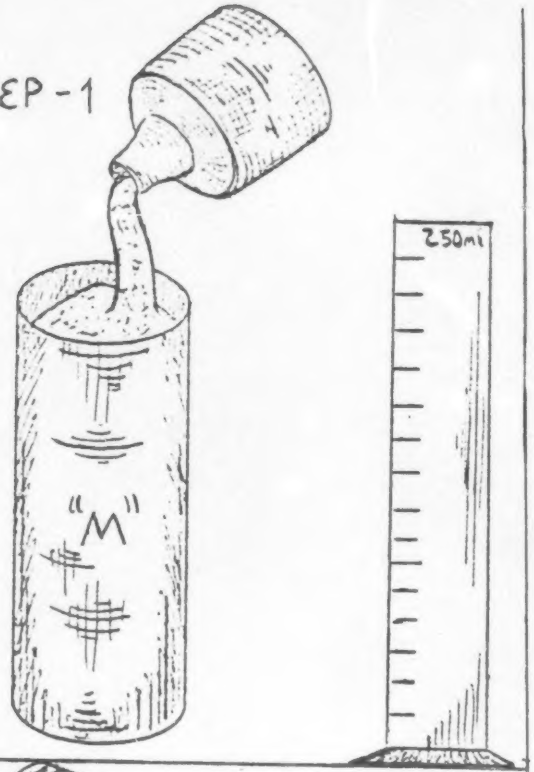

250
230
210
190
170
150
130
110
90
70
50
30
10

41. CONTAINER "L"--Look to the front of the classroom. Your teacher will be holding container "L" and a 250 milliliter graduate. The 250 milliliter graduate is drawn to scale in the picture on the right side of the next page. The drawings on the left side of the next page show container "L" drawn to scale as well as being filled with sand and then being emptied into the 250 milliliter graduate. Determine the capacity of container "L" by reading the scale of the graduate shown in Step 3. The shaded portion of the graduate in Step 3 represents the sand on the inside. Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

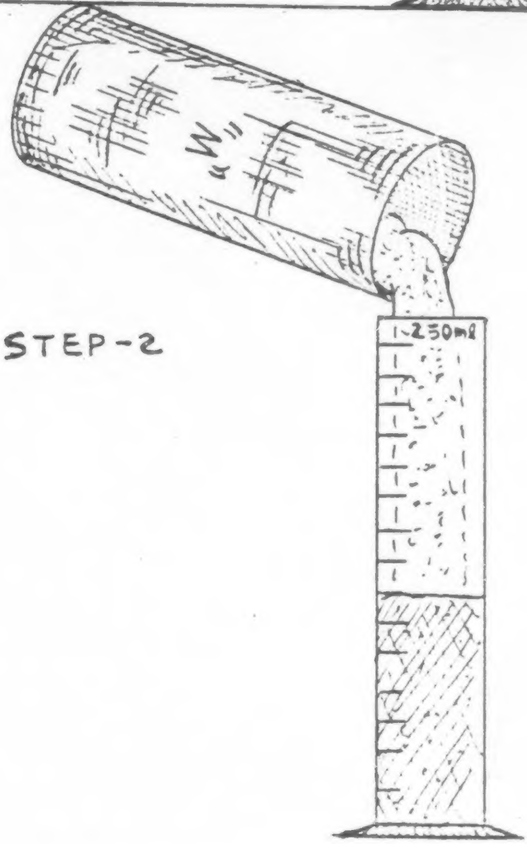

STEP-1
"L"
250ml
STEP-2
"L"
250ml
STEP-3
250
230
210
190
170
150
130
110
90
70
50
30
10

42. CONTAINER "M"--Look to the front of the classroom. Your teacher will be holding container "M" and a 250 milliliter graduate. The 250 milliliter graduate is drawn to scale in the picture on the right side of the next page. The drawings on the left side of the next page show container "M" drawn to scale as well as being filled with sand and then being emptied into the 250 milliliter graduate. Determine the capacity of container "M" by reading the scale of the graduate shown in Step 3. The shaded portion of the graduate in Step 3 represents the sand on the inside. Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

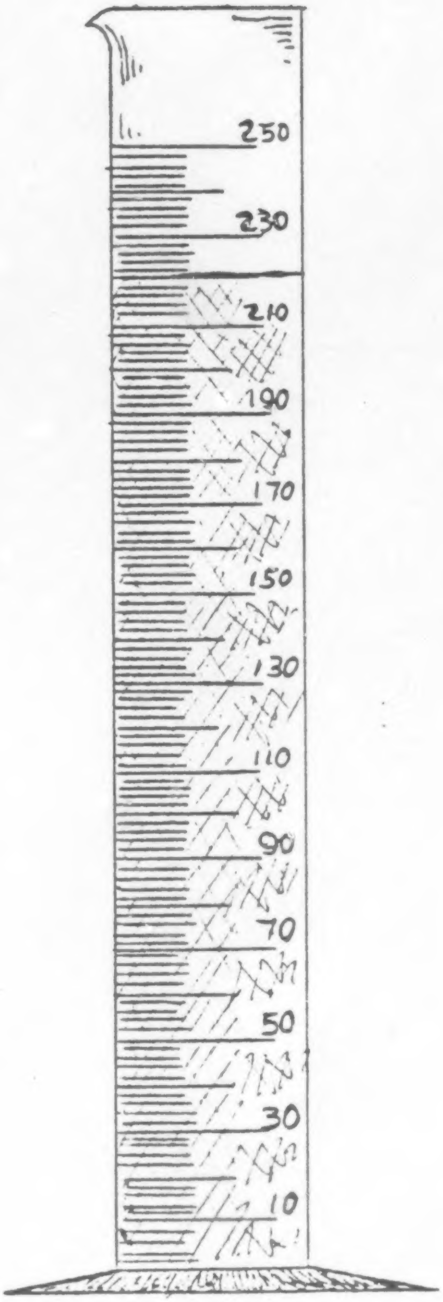
STEP-1



STEP-2



STEP-3


250
230
210
190
170
150
130
110
90
70
50
30
10

Please look at the clock and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Check all your answers with the KEY. You will find that the answers are not supplied for the ESTIMATE questions. There are no wrong answers for the Estimate questions. However, notice the difference, if any, between your Estimated Measurement answers and the actual Measurement answers. This will help to show how well you understand SI Measurement.

Answer Sheet for

Lesson 4--Simulated Activity

Student # ____________________ Teacher # ____________________

SECTION #1--Time Started ________________

1. V = ________ units^3
   (number)

2. V = ________ units^3
   (number)

3. V = ________ units^3
   (number)

4. V = ________ units^3
   (number)

SECTION #2

	ESTIMATE			MEASUREMENT
5.	______ ________ (number)(SI symbol)	←Compare→	8.	______ ________ (number)(SI symbol)
6.	______ ________ (number)(SI symbol)	←Compare→	9.	______ ________ (number)(SI symbol)
7.	______ ________ (number)(SI symbol)	←Compare→	10.	______ ________ (number)(SI symbol)

SECTION #3

11. 1 dm^3 = ________ ℓ
(number)

12. 3 dm^3 = ________ ℓ
(number)

13. ________ dm^3 = 15 ℓ
(number)

14. ________ dm^3 = 9 ℓ
(number)

15. 7 dm^3 = ________ ____________
(number) (SI symbol)

16. ________ ____________ = 12 ℓ
(number) (SI symbol)

SECTION #4

	ESTIMATE			MEASUREMENT
17.	________ ____________ (number)(SI symbol)	←Compare→	19.	________ ____________ (number)(SI symbol)
18.	________ ____________ (number)(SI symbol)	←Compare→	20.	________ ____________ (number)(SI symbol)

SECTION #6

	ESTIMATE			MEASUREMENT
21.	______ ______ (number)(SI symbol)	←Compare→	25.	______ ______ (number)(SI symbol)
22.	______ ______ (number)(SI symbol)	←Compare→	26.	______ ______ (number)(SI symbol)
23.	______ ______ (number)(SI symbol)	←Compare→	27.	______ ______ (number)(SI symbol)
24.	______ ______ (number)(SI symbol)	←Compare→	28.	______ ______ (number)(SI symbol)

SECTION #7

29. 1 mℓ = ______ (number) cm^3

30. 2 000 cm^3 = ______ (number) ℓ

31. 5 000 mℓ = ______ (number) ℓ

32. 2 000 cm^3 = ______ (number) dm^3

33. ______ (number) mℓ = 9 ℓ

34. 18 000 cm^3 = ______ (number) ℓ

SECTION #8

ESTIMATE **MEASUREMENT**

35. ______ ______ ←Compare→ 39. ______ ______
(number)(SI symbol) (number)(SI symbol)

36. ______ ______ ←Compare→ 40. ______ ______
(number)(SI symbol) (number)(SI symbol)

37. ______ ______ ←Compare→ 41. ______ ______
(number)(SI symbol) (number)(SI symbol)

38. ______ ______ ←Compare→ 42. ______ ______
(number)(SI symbol) (number)(SI symbol)

Time Completed ______________

MASS/WEIGHT
IN
SI MEASUREMENT

Lesson 5

SIMULATED ACTIVITIES

General Directions

Please do not write in this booklet. A special answer sheet, which will be supplied by your teacher, will be used to record your answers. You will need to supply your own soft lead pencil.

You will be asked to record the time when you start an activity (Time Started) and the time when you complete an activity (Time Completed). Please take special care to record these times on your answer sheet.

Lesson 5

Mass/Weight Measurement Activities

SECTION #1

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Mass is a measure of the amount of material that is contained in an object. The mass of an object can be found by using a balance scale and mass set or mass pieces such as those pictured below. The balance scale will compare the mass of an object in one pan with the mass of a known standard in the other pan.

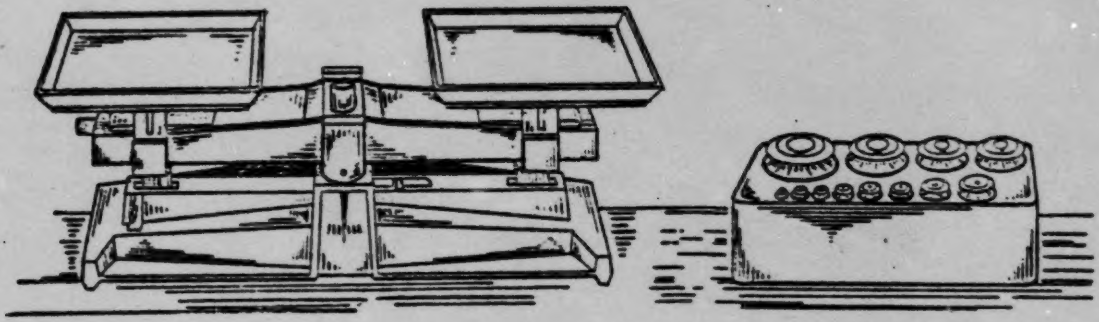


Figure #1

It is very important that you learn how to use the balance scale so that you will be able to compare unknown masses with a mass. First locate the pointer on the balance scale in Figure #1 above. It is located in the center of the balance scale and happens to be pointing straight down in the example in Figure #1.

Notice what happens to the pointer in Figure #2 as well as to the pan on the right when a mass piece is placed on the right pan of the balance. The pointer moved to the left.

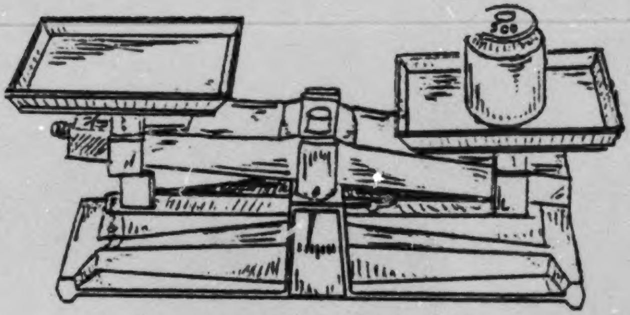


Figure #2

Now observe what happens to the pointer in Figure #3 when the same mass piece is removed from the right pan and placed on the left pan. The mass moved the pointer to the right and pushed the left pan down.

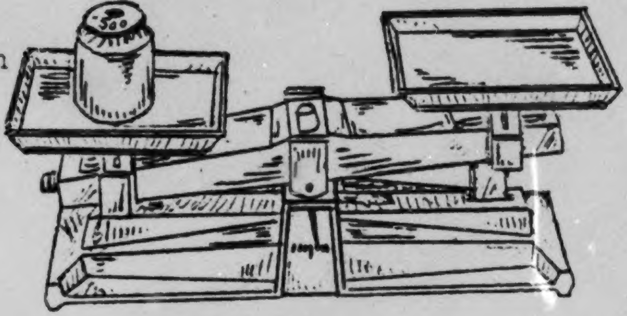
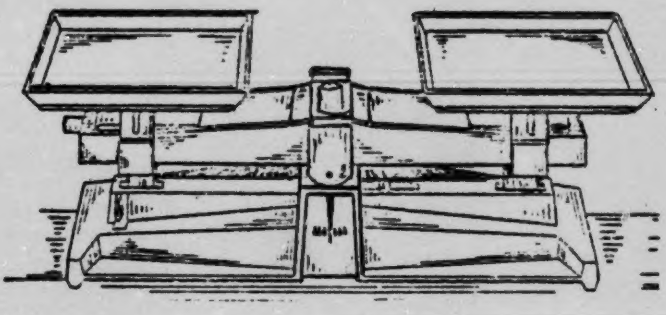


Figure #3

The picture to the right shows what should happen when the pans of the balance are empty. Notice how the pointer is on the long line. This means that the scale is balanced.

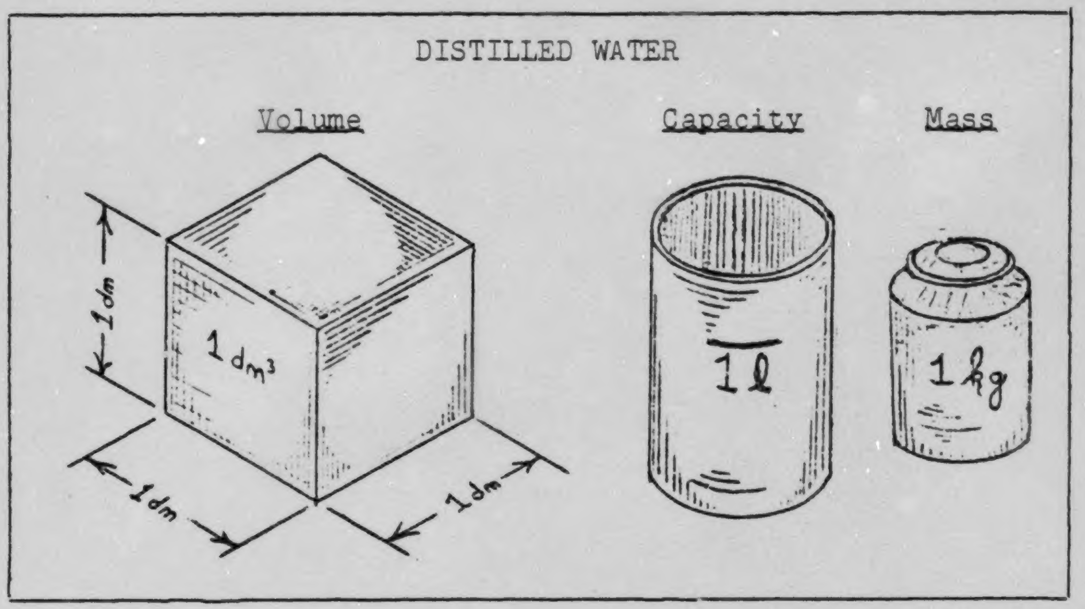


Balanced

Key Point If the pointer fails to line up with the long line when both pans are empty, ask your teacher for help.

Kilogram

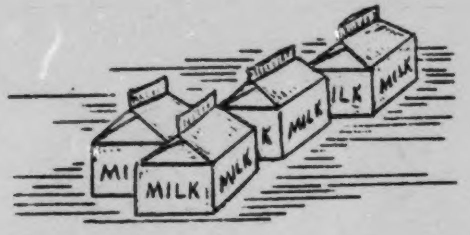
The kilogram is the basic unit of mass in SI Measurement. The symbol for kilogram is written as the small letters "kg". In SI Measurement there is a relationship between the volume, capacity and mass of distilled water under standard atmospheric conditions as is shown by the following drawing:



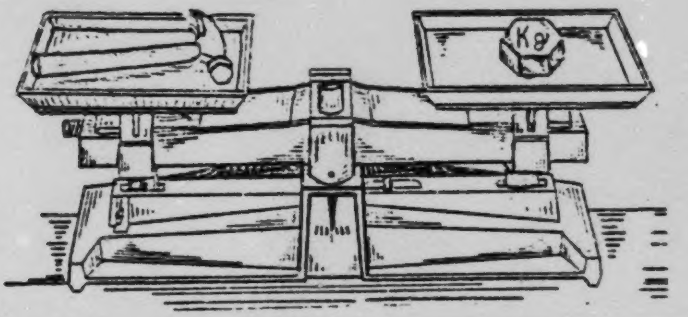
Key Point one cubic decimeter of water = one liter of water = one kilogram

Distilled water is used to show this relationship between volume, capacity and mass because distilled water does not contain varying amounts of minerals which makes some tap (drinking) water heavier or lighter than another. It should be pointed out, though, that there is very little difference between the mass of distilled or tap water.

A kilogram is a large unit of mass. Altogether, four cartons of milk (the kind you can get in your school cafeteria) have a mass of about 1 kilogram.



A hammer also has a mass of approximately 1 kilogram. A hammer placed on one pan of a balance will just about balance a 1 kilogram mass piece which is placed on the other pan as is shown in the example below. Notice that the pointer is pointing straight down which indicates the scale is balanced.



PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item number.

1. 1 ℓ of water = ___?___ kg
(number)

2. 1 dm^3 of water = ___?___ kg
(number)

3. $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ ℓ of water = 15 kg

4. $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ dm^3 of water = 9 kg

5. 6 ℓ of water = 6 $\underset{\text{(SI symbol)}}{\underline{\quad ? \quad}}$ of mass

6. 12 dm^3 of water = 12 $\underset{\text{(SI symbol)}}{\underline{\quad ? \quad}}$ of capacity

SECTION #2

Simulated Activities:

7. Look to the front of the classroom. Your teacher will be holding the liter measure that is drawn to scale in Figure 1 below. The other drawings are used to show you how to measure the mass of the liter measure when it is filled with water. First, the 1 kilogram mass piece is placed on the right pan of the balance as is shown in Step #1. The empty 1 liter measure is then placed on the left pan of the balance as is shown in Step #2. Water is then poured into the empty liter measure as is shown in Step #2 until the scale balances as is shown in Step #3.

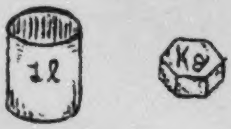
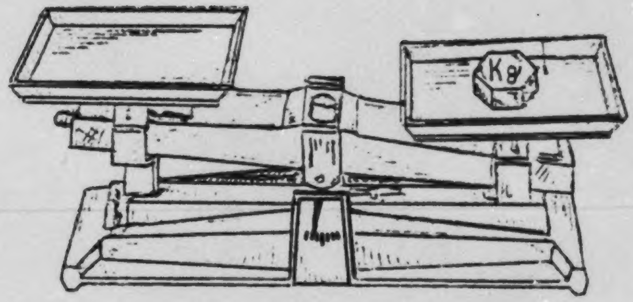
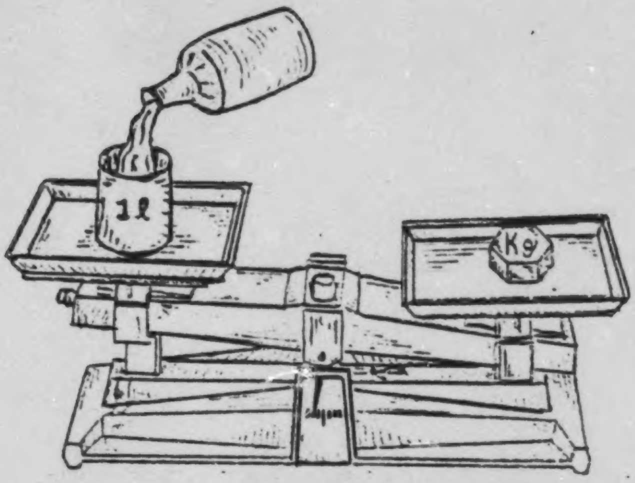


Figure 1

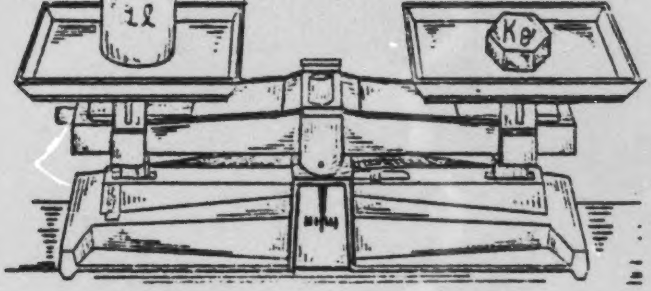


Step #1

(Question 7 is continued on next page)



Step #2



Step #3

You are to now determine the mass, in kilograms (kg), of the liter measure of water. Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

8. What is the mass, in kilograms (kg), of Object "N" which is shown in Figure 2? The drawings below are used to show you how the mass of Object "N" would be measured. First, Object "N" is placed on the left pan of the balance as is shown in Step #1. The kilogram mass piece is then placed on the right pan of the balance as is shown in Step #2.

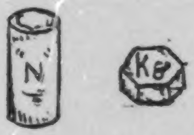
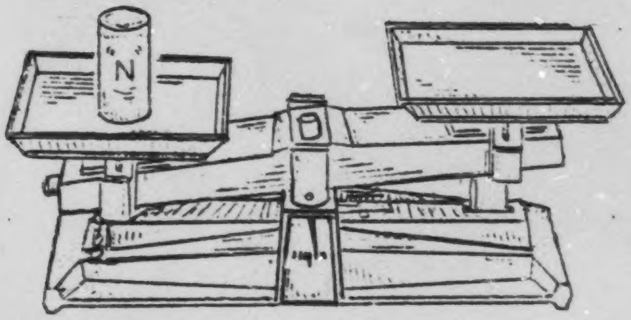
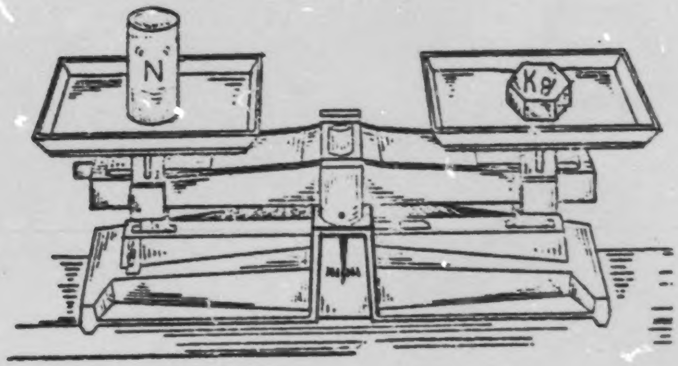


Figure 2



Step #1



Step #2

You are to determine the mass, in kilograms (kg), of Object "N". Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

SECTION #3

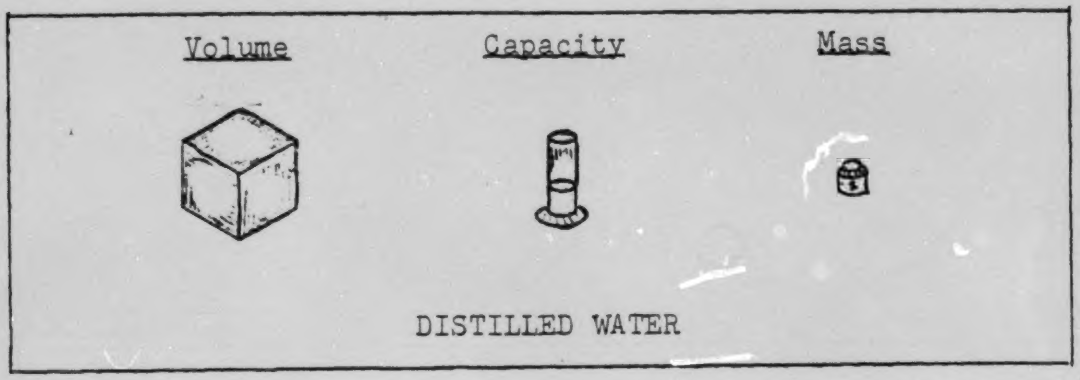
Gram

Sometimes a kilogram is not the best SI unit to use for measuring the mass of an object. This is the case when the object to be measured is much lighter than a kilogram. Therefore a small SI unit of mass is needed when small objects are to be measured. The smaller mass is called a gram. You will recall that it takes one thousand grams to equal one kilogram and that the prefix "kilo" means 1 000.

The symbol for gram is the small letter "g".

Key Point 1 000 g = 1 kg

The drawing below shows how the SI units of volume, capacity, and mass are related in SI Measurement. You should note that one cubic centimeter (1 cm^3) of distilled water has a capacity of one milliliter (1 mℓ). The mass of this amount of distilled water is 1 gram (1 g).



Key Point one cubic centimeter of water = one milliliter of water = one gram

PRACTICE PROBLEMS:

Change each quantity below to its equivalent. Write your answers on the answer sheet beside the corresponding item number.

9. 1 kg = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ g

10. 4 kg = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ g

11. 9 $\underset{\text{(SI symbol)}}{\underline{\quad ? \quad}}$ = 9 000 g

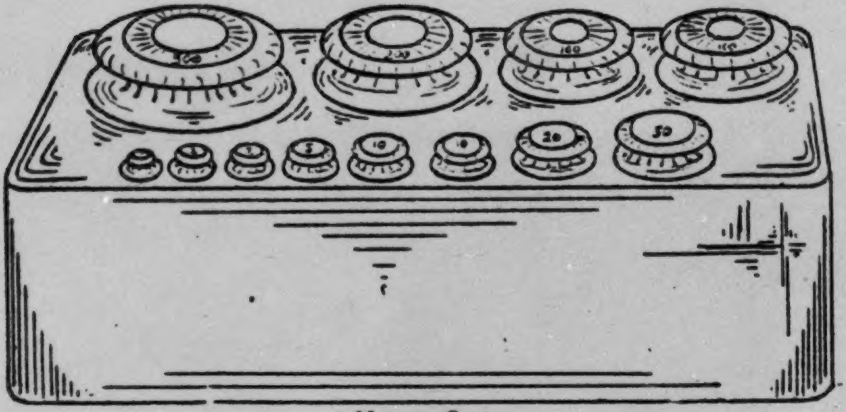
12. $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ kg = 5 000 g

13. 500 mℓ of water = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ g

14. 100 cm^3 of water = $\underset{\text{(number)}}{\underline{\quad ? \quad}}$ g

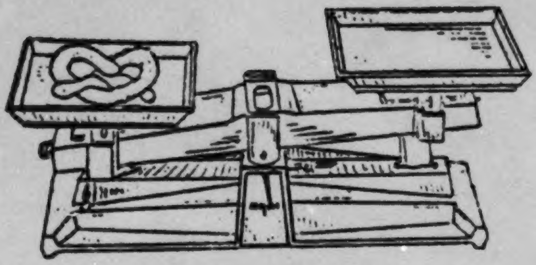
The gram is a small SI unit of mass. One thumbtack has a mass of approximately 1 gram while a nickel has a mass of approximately 5 grams. Your writing pencil, when it was new, had a mass of about 5 grams.

It is important at this time that you learn how to measure the mass of an object in grams by using the balance and the mass pieces which are located in the mass set. The mass set includes the following gram pieces:

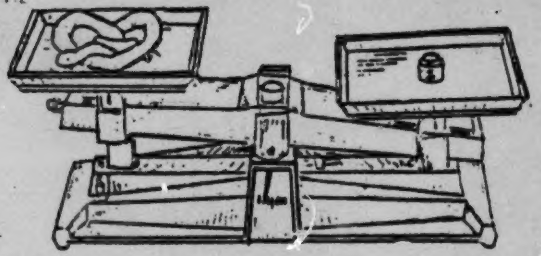


Mass Set

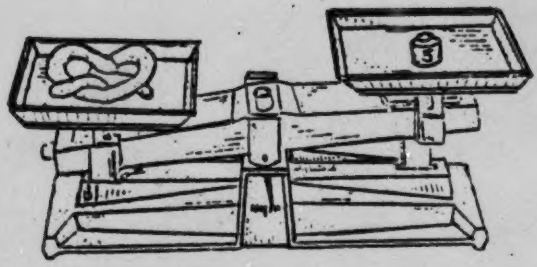
The drawings on the next page show you how to find the mass of one extra thick pretzel. First you place the pretzel on the left pan of the balance (Step 1). Next you follow a simple set of steps by first placing the 1 gram (1 g) mass piece on the right pan (Step 2). Notice that the 1 gram (1 g) mass piece fails to balance the scale, as does the 2 gram (2 g) mass piece (Step 3), and the 5 gram (5 g) mass piece (Step 4). However Step 5 shows that the 10 gram (10 g) mass piece is heavier than the mass of one pretzel. We know then from Steps 4 and 5 that the pretzel has a mass that is somewhere between 5 grams (5 g) and 10 grams (10 g) because the 5 gram (5 g) mass piece is too light, while the 10 gram (10 g) mass piece is too heavy. The mass of the one extra thick pretzel can finally be determined by combining two masses (5 g and 2 g) to balance the scales as shown in Step 6. The mass of the one pretzel is found by adding the two masses (5 g + 2 g) for a total of 7 grams. We can therefore say that one extra thick pretzel has a mass of approximately 7 grams (7 g).



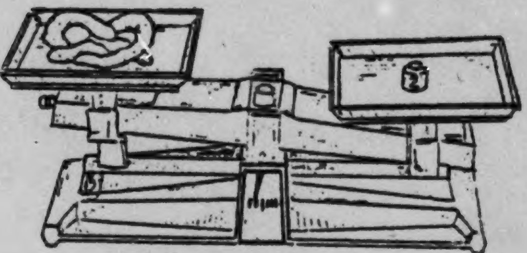
Step #1



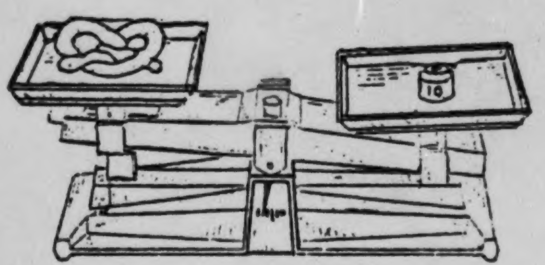
Step #2



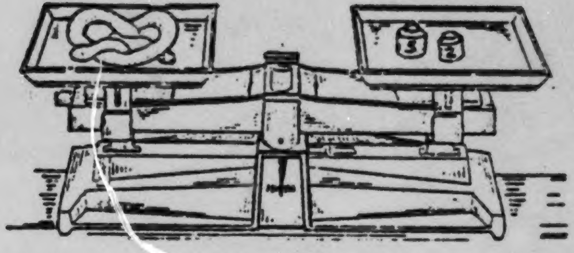
Step #3



Step #4



Step #5



Step #6

*This page is reduced 23% from the original.

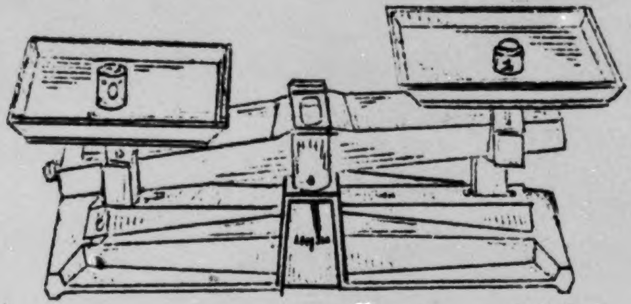
SECTION #4

Simulated Activities:

Problem Set A:

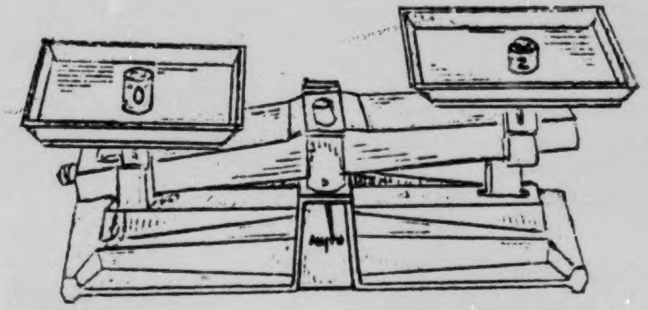
What is the mass, in grams (g), of Object "O"? Object "O" is shown below on the left pan of the balances.

15. A 1 gram mass piece from the mass set has been placed on the right pan in the picture below.



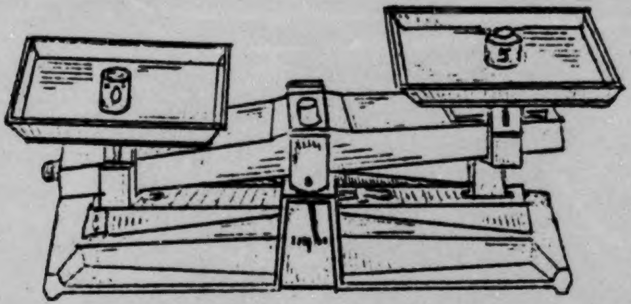
Is the mass of Object "O" less than, the same as or more than 1 gram? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

16. Below you see that the 1 gram mass piece on the right pan has been replaced with a 2 gram mass piece.



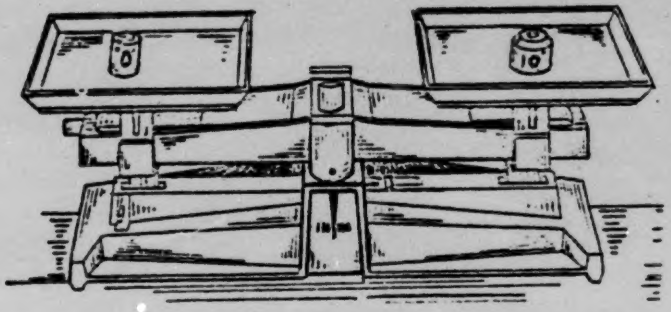
Is the mass of Object "O" less than, the same as or more than 2 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

17. Below you see that the 2 gram mass piece on the right pan has been replaced with a 5 gram mass piece.



Is the mass of Object "O" less than, the same as or more than 5 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

18. Below you see that the 5 gram mass piece on the right pan has been replaced with a 10 gram mass piece.



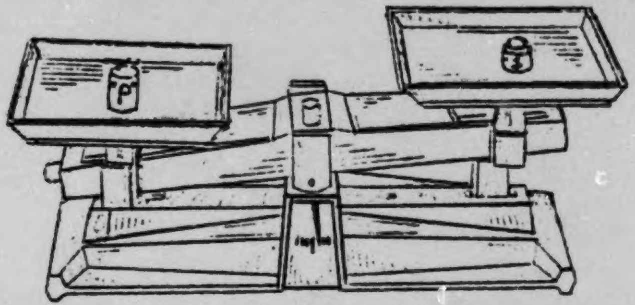
Is the mass of Object "O" less than, the same as or more than 10 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

19. By now you probably have observed that the mass of Object "O" is the same as one of the measures that was pictured. You are therefore to write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

Problem Set B:

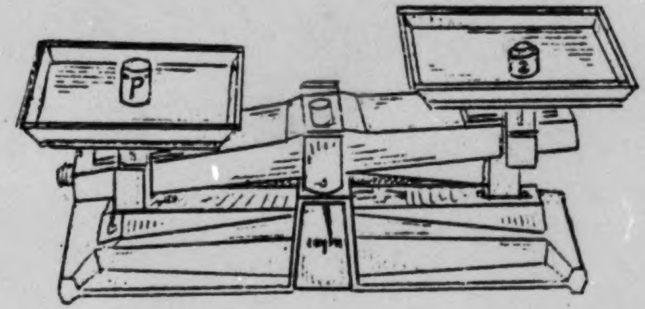
What is the mass, in grams (g), of Object "P"? Object "P" is shown below on the left pan of the balances.

20. A 1 gram mass piece from the mass set has been placed on the right pan in the picture below.



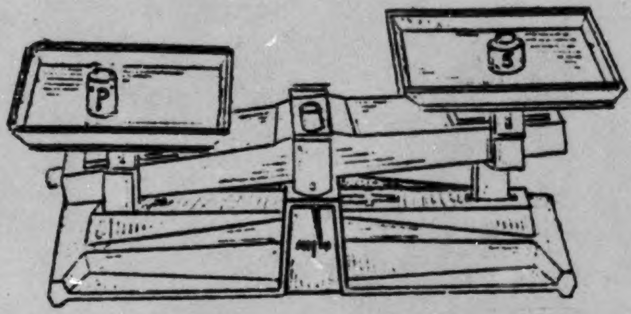
Is the mass of Object "P" less than, the same as or more than 1 gram? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

21. Below you see that the 1 gram mass piece on the right pan has been replaced with a 2 gram mass piece.



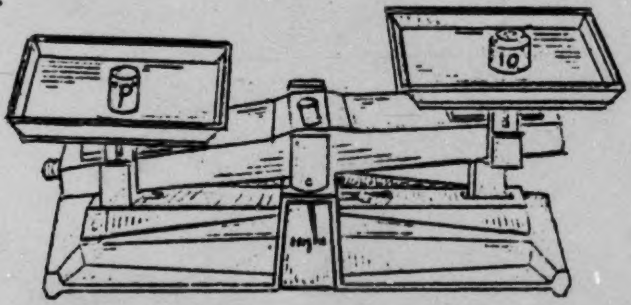
Is the mass of Object "P" less than, the same as or more than 2 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

22. Below you see that the 2 gram mass piece on the right pan has been replaced with a 5 gram mass piece.



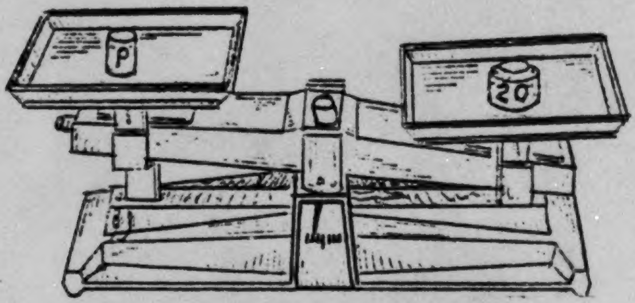
Is the mass of Object "P" less than, the same as or more than 5 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

23. Below you see that the 5 gram mass piece on the right pan has been replaced with a 10 gram mass piece.



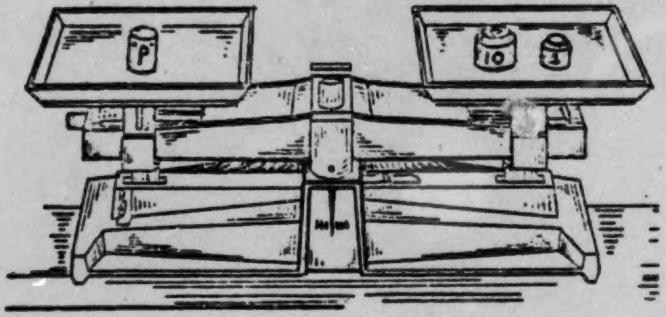
Is the mass of Object "P" less than, the same as or more than 10 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

24. Below you see that the 10 gram mass piece on the right pan has been replaced with a 20 gram mass piece.



Is the mass of Object "P" less than, the same as or more than 20 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

25. Below you see that the 20 gram mass piece has been replaced with a 10 gram mass piece and a 1 gram mass piece.



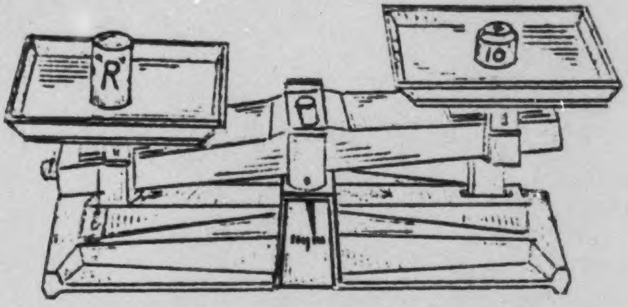
Is the mass of Object "P" less than, the same as or more than 11 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

26. By now you probably have observed that the mass of Object "P" is the same as one of the measures that was pictured. You are therefore to write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

Problem Set C:

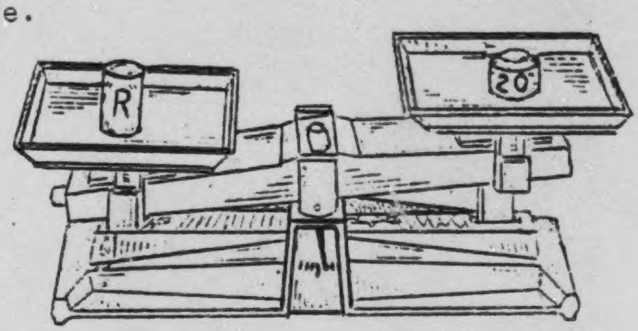
What is the mass, in grams (g), of Object "R"? Object "R" is shown below on the left pan of the balances.

27. A 10 gram mass piece from the mass set has been placed on the right pan in the picture below.



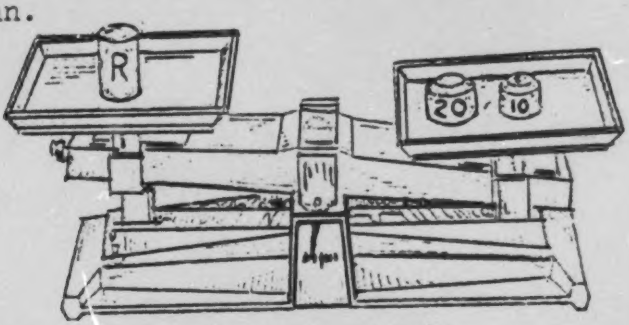
Is the mass of Object "R" less than, the same as or more than 10 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

28. Below you see that the 10 gram mass piece on the right pan has been replaced with a 20 gram mass piece.



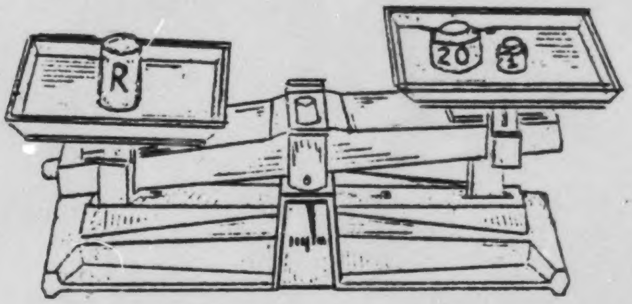
Is the mass of Object "R" less than, the same as or more than 20 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

29. Below you see that a 10 gram mass piece was added to the 20 gram mass piece on the right pan.



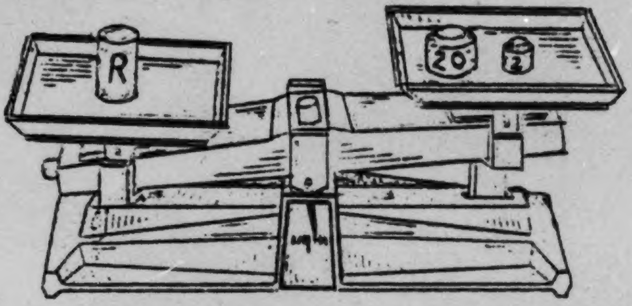
Is the mass of Object "R" less than, the same as or more than 30 grams (10 g + 20 g = 30 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

30. Below you see that the 10 gram mass piece shown above on the right pan has been replaced with a 1 gram mass piece.



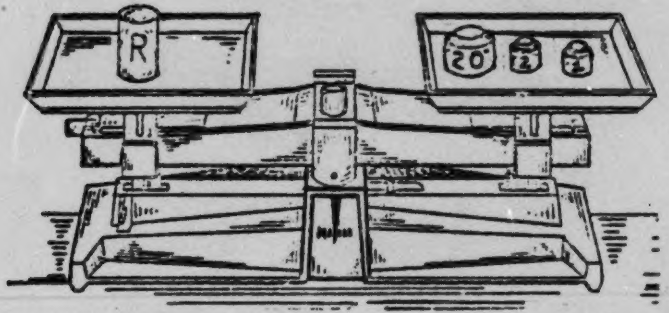
Is the mass of Object "R" less than, the same as or more than 21 grams (20 g + 1 g = 21 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

31. Below you see that the 1 gram mass piece shown on the preceding page on the right pan was replaced with a 2 gram mass piece.



Is the mass of Object "R" less than, the same as or more than 22 grams (20 g + 2 g = 22 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

32. Below you see that an additional 1 gram mass piece was added to the 20 gram and 2 gram mass pieces on the right pan.



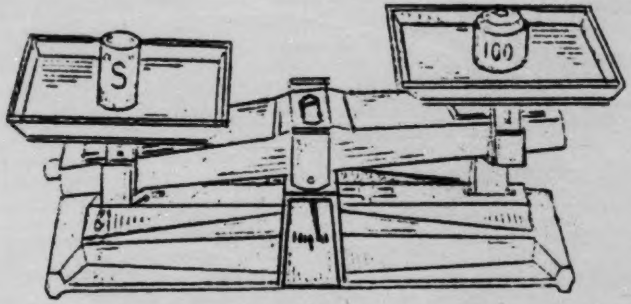
Is the mass of Object "R" less than, the same as or more than 23 grams (20 g + 2 g + 1 g = 23 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

33. By now you probably have observed that the mass of Object "R" is the same as one of the measures that was pictured. You are therefore to write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

Problem Set D:

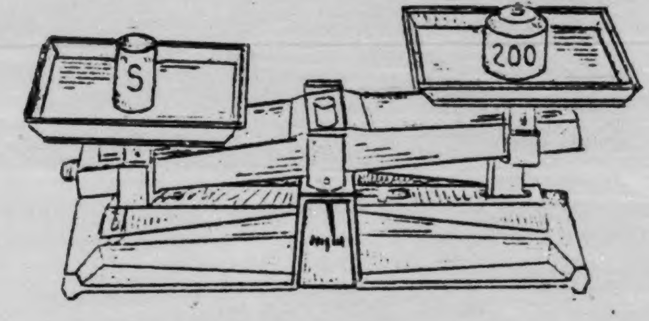
What is the mass, in grams (g), of Object "S"? This activity applies to an object whose mass is more than 50 grams. Object "S" is shown below on the left pan of the balances.

34. A 100 gram mass piece from the mass set has been placed on the right pan in the picture below.



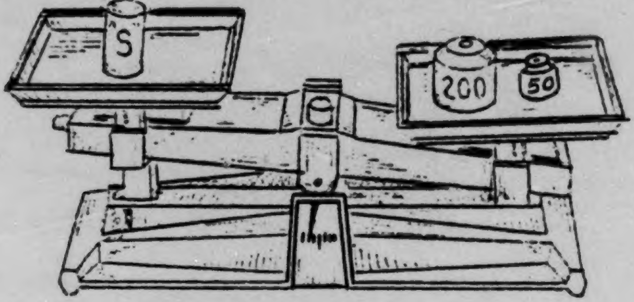
Is the mass of Object "S" less than, the same as or more than 100 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

35. Below you see that the 100 gram mass piece on the right pan has been replaced with a 200 gram mass piece.



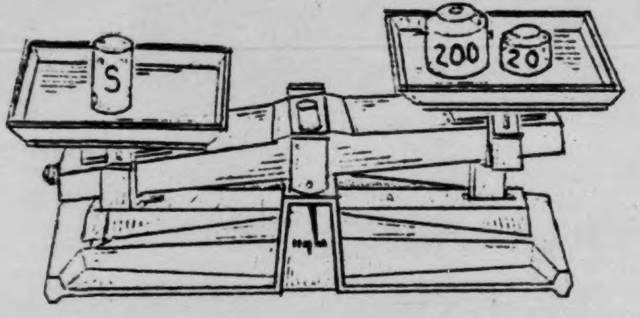
Is the mass of Object "S" less than, the same as or more than 200 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

36. Below you see that an additional 50 gram mass piece was added to the 200 gram mass piece on the right pan.



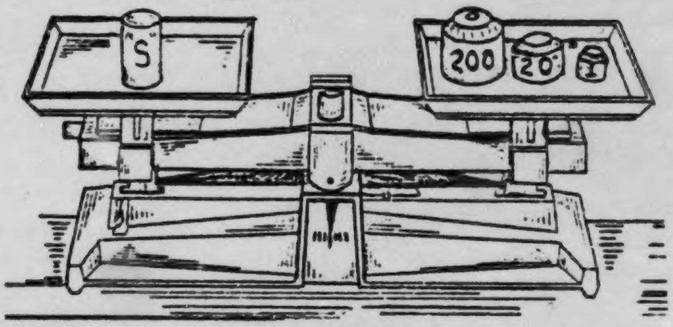
Is the mass of Object "S" less than, the same as or more than 250 grams? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

37. Below you see that the 50 gram mass piece shown above on the right pan has been replaced with a 20 gram mass piece.



Is the mass of Object "S" less than, the same as or more than 220 grams (200 g + 20 g = 220 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

38. Below you see that an additional 1 gram mass piece was added to the 200 gram and 20 gram mass pieces on the right pan.



Is the mass of Object "S" less than, the same as or more than 221 grams (200 g + 20 g + 1 g = 221 g)? Circle the letter before the correct statement on the answer sheet beside the corresponding item number.

39. By now you probably have observed that the mass of Object "S" is the same as one of the measures that was pictured. You are therefore to write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

Please look at the clock again and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Check all your answers with the KEY.

Answer Sheet for
Lesson 5--Simulated Activity

Student # ________________ Teacher # ________________

SECTION #1--Time Started ________________

1. 1 ℓ of water = ________ kg
   (number)

2. 1 dm^3 of water = ________ kg
   (number)

3. ________ ℓ of water = 15 kg
   (number)

4. ________ dm^3 of water = 9 kg
   (number)

5. 6 ℓ of water = 6 __________ of mass
   (SI symbol)

6. 12 dm^3 of water = 12 __________ of capacity
   (SI symbol)

SECTION #2

7. Liter measure filled with water has a mass of
   ________ __________.
   (number) (SI symbol)

8. Object "N" has a mass of ________ __________.
   (number) (SI symbol)

SECTION #3

9. 1 kg = ________ g
(number)

10. 4 kg = ________ g
(number)

11. 9 ____________ = 9 000 g
(SI symbol)

12. ________ kg = 5 000 g
(number)

13. 500 mℓ of water = ________ g
(number)

14. 100 cm^3 of water = ________ g
(number)

SECTION #4

Problem Set A: (Circle the letter before the correct statement for each of the following questions.)

15.

a. Object "O" has less mass than does the 1 gram mass piece.
b. Object "O" has the same mass as does the 1 gram mass piece.
c. Object "O" has more mass than does the 1 gram mass piece.

16.

a. Object "O" has *less* mass than does the 2 gram mass piece.

b. Object "O" has the *same* mass as does the 2 gram mass piece.

c. Object "O" has *more* mass than does the 2 gram mass piece.

17.

a. Object "O" has *less* mass than does the 5 gram mass piece.

b. Object "O" has the *same* mass as does the 5 gram mass piece.

c. Object "O" has *more* mass than does the 5 gram mass piece.

18.

a. Object "O" has *less* mass than does the 10 gram mass piece.

b. Object "O" has the *same* mass as does the 10 gram mass piece.

c. Object "O" has *more* mass than does the 10 gram mass piece.

19. Object "O" was found to have a mass of

__________ ______________.
(number) (SI symbol)

Problem Set B: (Circle the letter before the correct statement for each of the following questions.)

20.

a. Object "P" has less mass than does the 1 gram mass piece.

b. Object "P" has the same mass as does the 1 gram mass piece.

c. Object "P" has more mass than does the 1 gram mass piece.

21.

a. Object "P" has less mass than does the 2 gram mass piece.

b. Object "P" has the same mass as does the 2 gram mass piece.

c. Object "P" has more mass than does the 2 gram mass piece.

22.

a. Object "P" has less mass than does the 5 gram mass piece.

b. Object "P" has the same mass as does the 5 gram mass piece.

c. Object "P" has more mass than does the 5 gram mass piece.

23.

a. Object "P" has less mass than does the 10 gram mass piece.

b. Object "P" has the same mass as does the 10 gram mass piece.

c. Object "P" has more mass than does the 10 gram mass piece.

24.

a. Object "P" has less mass than does the 20 gram mass piece.

b. Object "P" has the same mass as does the 20 gram mass piece.

c. Object "P" has more mass than does the 20 gram mass piece.

25.

a. Object "P" has less mass than do the 11 gram mass pieces.

b. Object "P" has the same mass as do the 11 gram mass pieces.

c. Object "P" has more mass than do the 11 gram mass pieces.

26. Object "P" was found to have a mass of

__________ ______________.
(number) (SI symbol)

Problem Set C: (Circle the letter before the correct statement for each of the following questions.)

27.

a. Object "R" has less mass than does the 10 gram mass piece.

b. Object "R" has the same mass as does the 10 gram mass piece.

c. Object "R" has more mass than does the 10 gram mass piece.

28.

a. Object "R" has less mass than does the 20 gram mass piece.

b. Object "R" has the same mass as does the 20 gram mass piece.

c. Object "R" has more mass than does the 20 gram mass piece.

29.

a. Object "R" has less mass than does the 30 gram mass piece.

b. Object "R" has the same mass as does the 30 gram mass piece.

c. Object "R" has more mass than does the 30 gram mass piece.

30.

a. Object "R" has less mass than do the 21 gram mass pieces.

b. Object "R" has the same mass as do the 21 gram mass pieces.

c. Object "R" has more mass than do the 21 gram mass pieces.

31.

a. Object "R" has less mass than do the 22 gram mass pieces.

b. Object "R" has the same mass as do the 22 gram mass pieces.

c. Object "R" has more mass than do the 22 gram mass pieces.

32.

a. Object "R" has less mass than do the 23 gram mass pieces.

b. Object "R" has the same mass as do the 23 gram mass pieces.

c. Object "R" has more mass than do the 23 gram mass pieces.

33. Object "R" was found to have a mass of

________ ___________.
(number) (SI symbol)

Problem Set D: (Circle the letter before the correct statement for each of the following questions.)

34.

a. Object "S" has less mass than does the 100 gram mass piece.

b. Object "S" has the same mass as does the 100 gram mass piece.

c. Object "S" has more mass than does the 100 gram mass piece.

35.

a. Object "S" has less mass than does the 200 gram mass piece.

b. Object "S" has the same mass as does the 200 gram mass piece.

c. Object "S" has more mass than does the 200 gram mass piece.

36.

a. Object "S" has less mass than do the 250 gram mass pieces.

b. Object "S" has the same mass as do the 250 gram mass pieces.

c. Object "S" has more mass than do the 250 gram mass pieces.

37.

a. Object "S" has *less* mass than do the 220 gram mass pieces.

b. Object "S" has the *same* mass as do the 220 gram mass pieces.

c. Object "S" has *more* mass than do the 220 gram mass pieces.

38.

a. Object "S" has *less* mass than do the 221 gram mass pieces.

b. Object "S" has the *same* mass as do the 221 gram mass pieces.

c. Object "S" has *more* mass than do the 221 gram mass pieces.

39. Object "S" was found to have a mass of

________ __________.
(number) (SI symbol)

Time Completed _______________

TEMPERATURE
IN
SI MEASUREMENT

Lesson 6

SIMULATED ACTIVITIES

General Directions

Please do not write in this booklet. A special answer sheet, which will be supplied by your teacher, will be used to record your answers. You will need to supply your own soft lead pencil.

You will be asked to record the time when you start an activity (Time Started) and the time when you complete an activity (Time Completed). Please take special care to record these times on your answer sheet.

Lesson 6

Temperature Measurement Activities

SECTION #1

Please look at the clock and record the correct time on your answer sheet. Do this at this time on the blank entitled, Time Started ________.

Temperature in SI Measurement is usually measured with a Celsius thermometer. Figure #1 is a drawing of a Celsius thermometer with its various parts labeled. The glass tube contains a red liquid that expands and raises as the temperature increases and contracts or lowers as the temperature decreases. The scale on the thermometer is used to indicate the position of the liquid and thus the temperature. The capital letter "C" at the top of the thermometer is the symbol for Celsius.

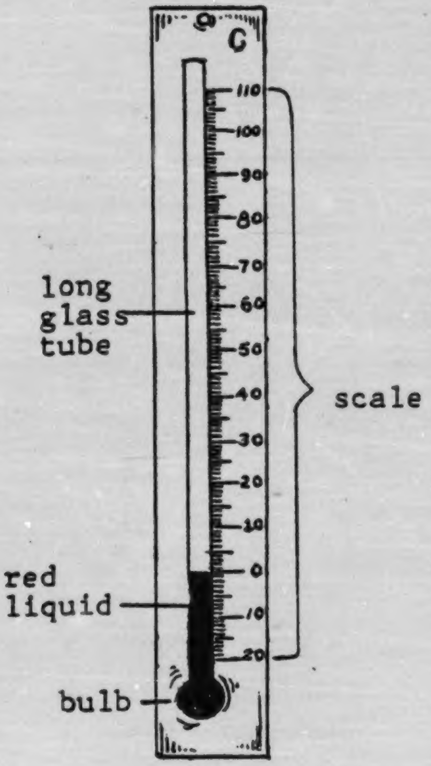


Figure #1

Did you notice the lines on the scale of the thermometer? Each line represents a number, but not all lines have numbers next to them.

Let's take a closer look at the part of the thermometer between 0 and 10 which is shown in Figure #2. Count the spaces between the 0 and the 10. You should have counted 10 spaces.

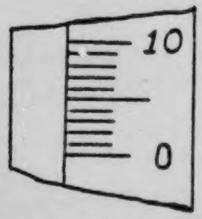


Figure #2

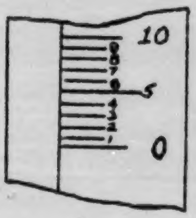


Figure #3

The first line above the line marked 0 stands for 1 as is shown in Figure #3. The next line stands for 2, and so on. Notice that line 5, which is half way between 0 and 10, is a little longer than the rest of the lines.

1. Look at your answer sheet. Next to number 1 you see a section of a Celsius temperature scale. Place the number the line stands for to the right of each line on the scale.

The units for measuring temperature are called degrees. Each line that you see on the scale of the Celsius thermometer stands for 1 degree. The small raised circle, "°" is the symbol that is used to represent degree.

Key Point When you use the Celsius scale to measure temperature, always write °C after the number which is the symbol for degree Celsius. This identifies the scale and the SI unit used.

The drawing in Figure #4 shows part of a Celsius thermometer. The liquid is two lines above 60. This thermometer shows a temperature of 62 °C.

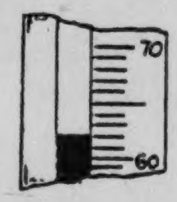


Figure #4

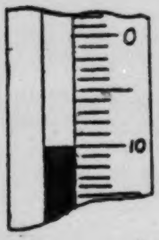


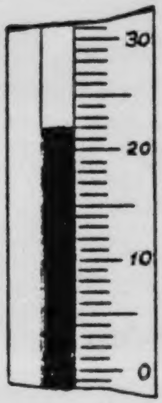
Figure #5

There are times when the temperature is below zero. Figure #5 shows a Celsius thermometer which reads, "10 °C below zero," or is read as "-10 °C."

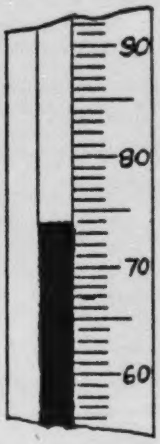
PRACTICE PROBLEMS:

Four drawings of Celsius thermometers are provided for clarification of measuring temperature in this SI unit. What temperature does each thermometer show? Write your answer along with the proper SI symbol on the answer sheet beside the corresponding item number.

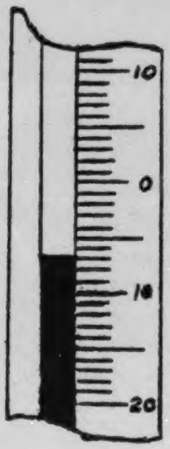
2.



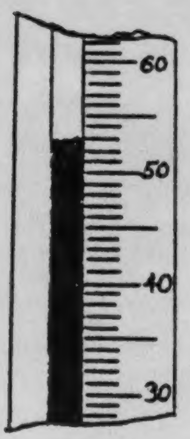
3.



4.



5.



Finally, temperature measurements will be more accurate if you follow these Key Points:

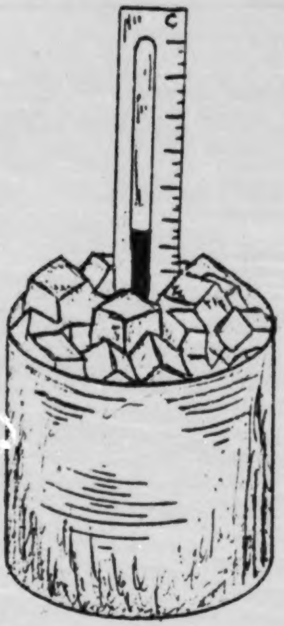
1. When measuring the temperature of a liquid, be sure the bulb, which is located at the bottom of the thermometer, is in the liquid.

2. Always hold the thermometer by the metal part. If your fingers are on the bulb, the heat from them can make the red liquid go up or down.

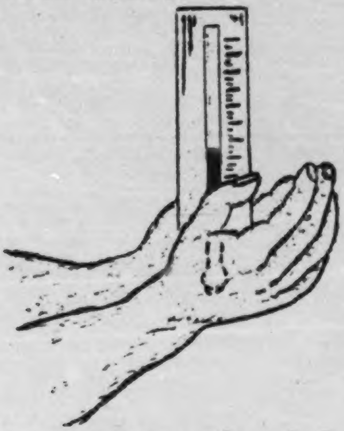
Simulated Activities:

6. Estimate the temperature of your classroom in Celsius units. Write your answer and the proper SI symbol on the answer sheet beside the corresponding item number.

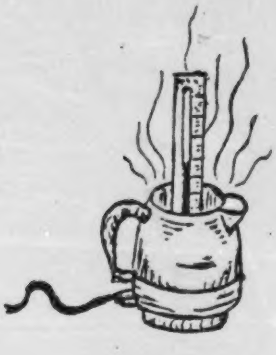
7. Estimate the temperature of a Celsius thermometer that is placed in a container of ice for 60 seconds. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.



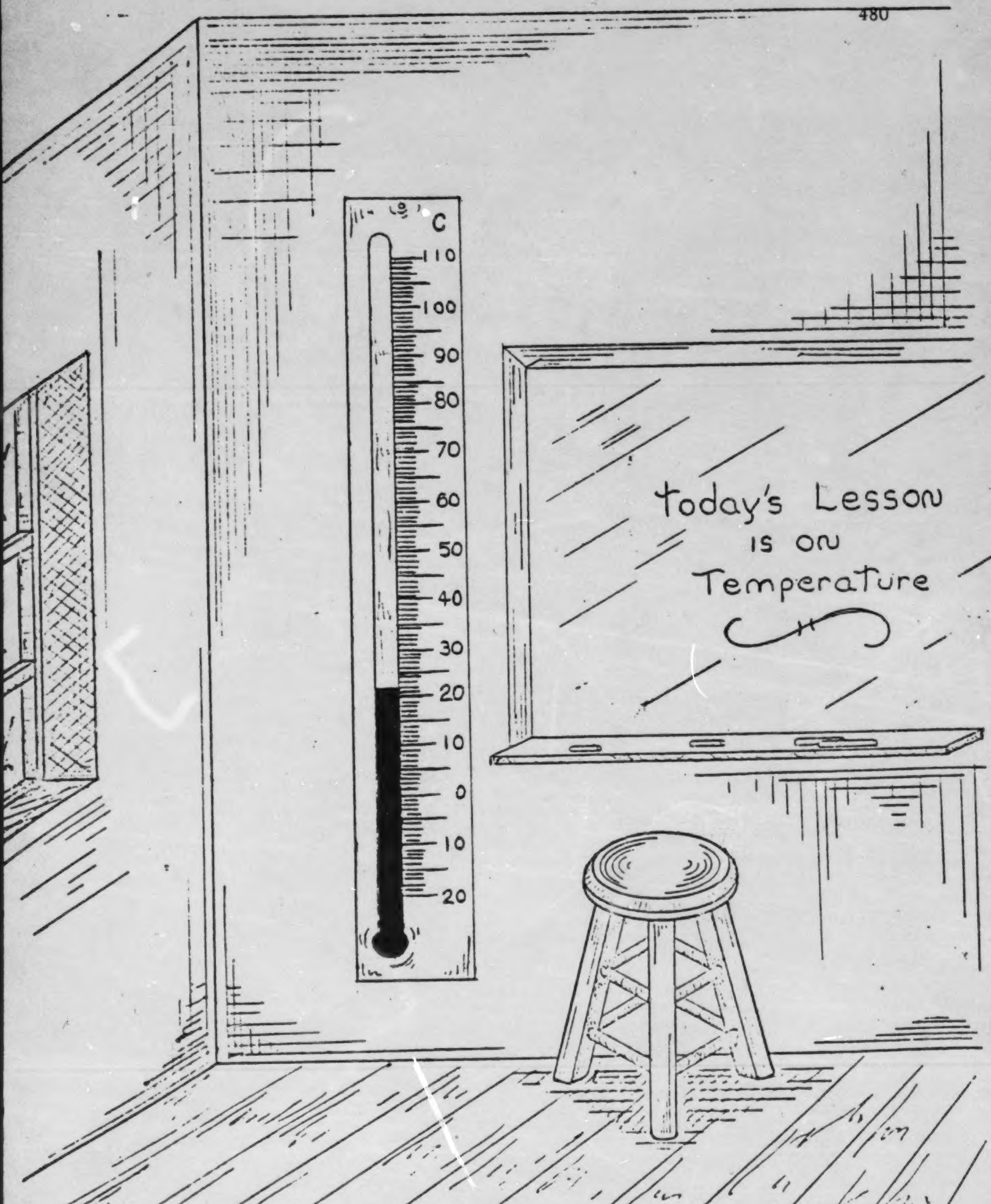
8. Estimate the temperature of a Celsius thermometer if you were holding the bulb of the thermometer between the palms of your hands for 60 seconds. The bulb, in this case, would be touching your palms. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.



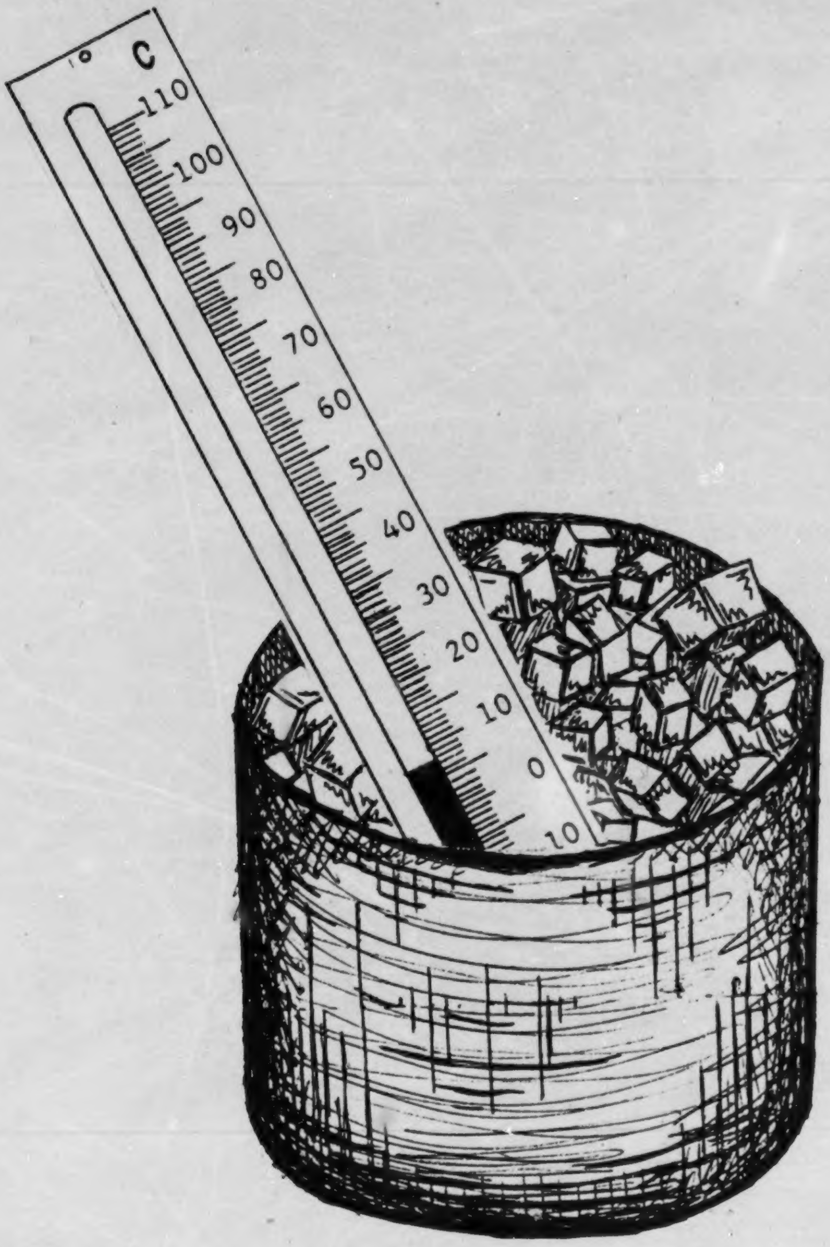
9. Estimate the temperature of a Celsius thermometer if you placed it in the heated water of a coffee pot for 60 seconds. Write your answer with the proper SI symbol on the answer sheet beside the corresponding item number.



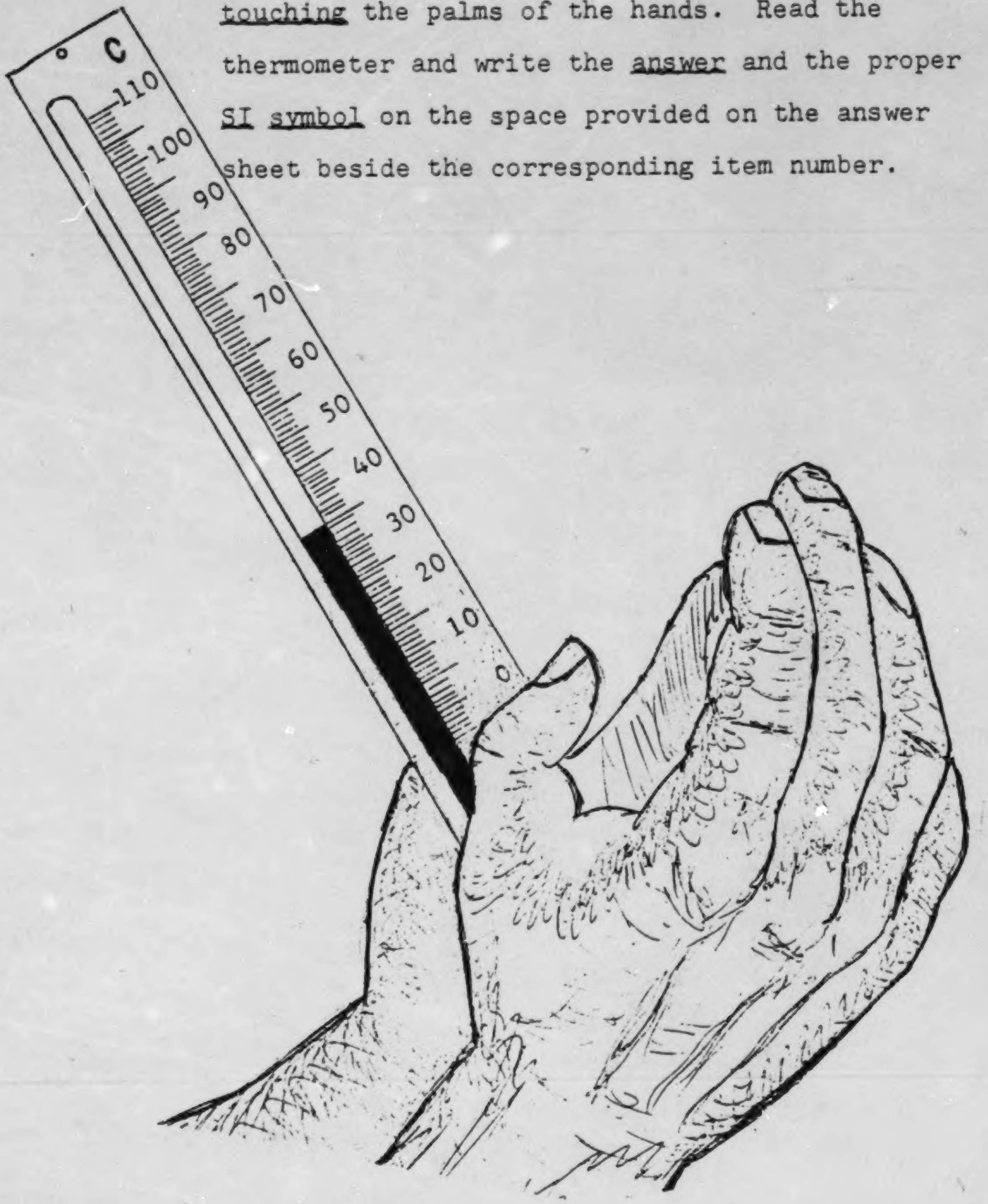
10. On the next page you see a picture of a Celsius thermometer upon which the temperature of your classroom has been recorded. Read the Celsius thermometer and write the answer and the proper SI symbol in the space provided on the answer sheet beside the corresponding item number.


C
110
100
90
80
70
60
50
40
30
20
10
0
10
20
Today's Lesson
is on
Temperature

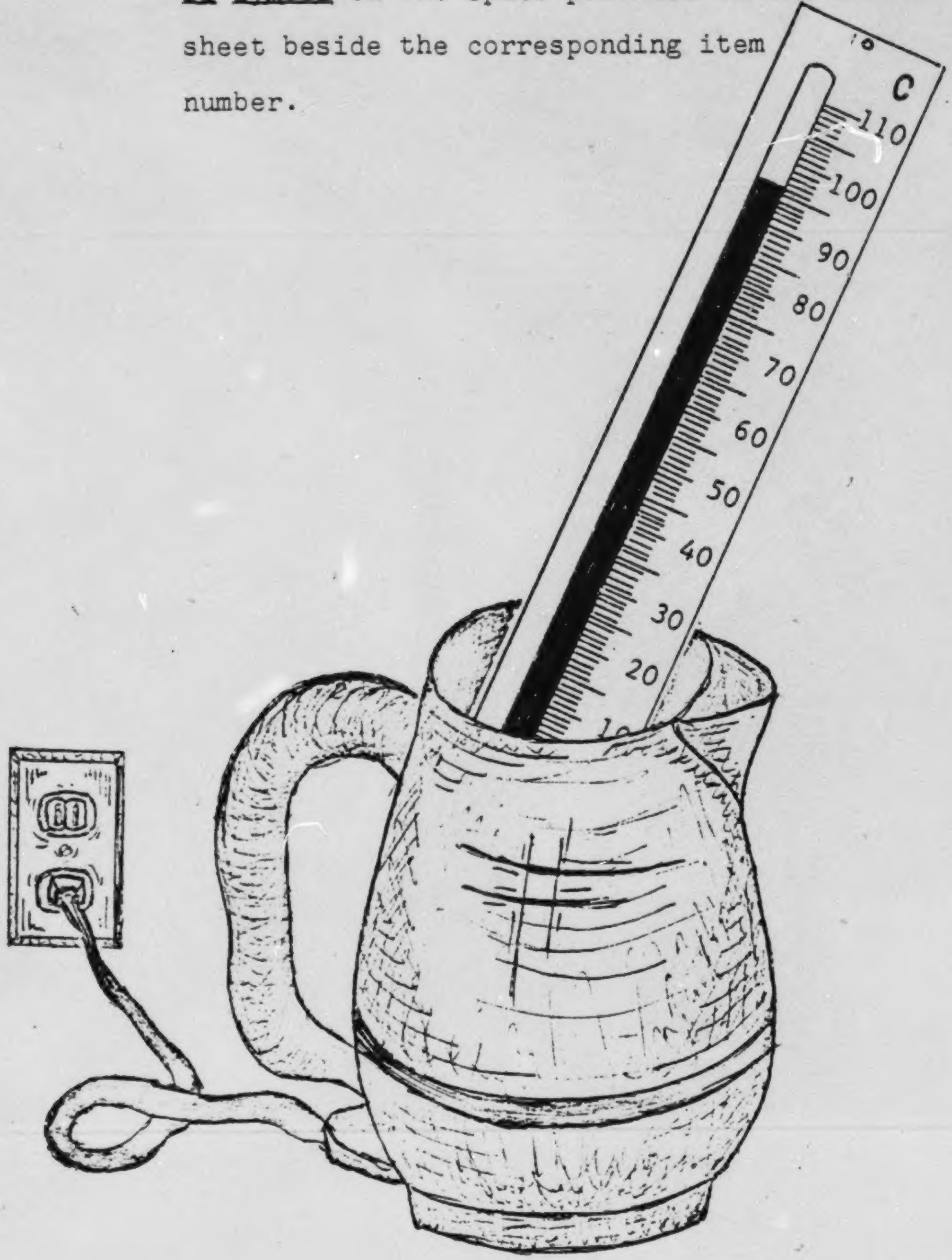
11. Below is pictured a Celsius thermometer that has been placed for 60 seconds in a container filled with ice. Read the thermometer and write the answer and the proper SI symbol on the space provided on the answer sheet beside the corresponding item number.


1°
C
110
100
90
80
70
60
50
40
30
20
10
0
10

12. Below is the picture of a Celsius thermometer in which the bulb of the thermometer has been placed between the palms of a person's hands for 60 seconds. The bulb of the thermometer is touching the palms of the hands. Read the thermometer and write the answer and the proper SI symbol on the space provided on the answer sheet beside the corresponding item number.



13. Below is a picture of a Celsius thermometer that has been placed in the heated water of a coffee pot for 60 seconds. Read the Celsius thermometer and write the answer and the proper SI symbol on the space provided on the answer sheet beside the corresponding item number.



Please look at the clock and record the correct time on your answer sheet beside the blank entitled, Time Completed ________.

Check all your answers with the KEY. You will find that the answers are not supplied for the Estimate questions. There are no wrong answers for Estimate questions. However, notice the difference, if any, between your Estimated measurement answers and the actual Measurement answers.

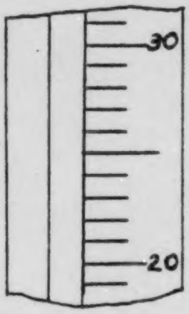
Answer Sheet for

Lesson 6--Simulated Activity

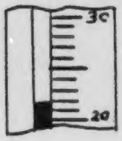
Student # ________________ Teacher # ________________

SECTION #1--Time Started ________________

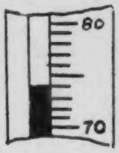
1.



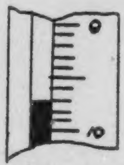
2. ______



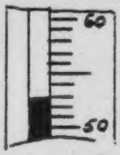
3. ______



4. ______



5. ______



ESTIMATE MEASUREMENT

6. ______ ______ ← Compare (classroom) → 10. ______ ______
(number)(SI symbol) (number)(SI symbol)

7. ______ ______ ← Compare (ice) → 11. ______ ______
(number)(SI symbol) (number)(SI symbol)

8. ______ ______ ← Compare (palms) → 12. ______ ______
(number)(SI symbol) (number)(SI symbol)

9. ______ ______ ← Compare (coffee pot) → 13. ______ ______
(number)(SI symbol) (number)(SI symbol)

Time Completed ________________

APPENDIX F

Final Instrument

Post-Test Examination--International System of Units

General Directions

1. This examination consists of 27 multiple choice questions.

2. A special answer sheet accompanies this test booklet.

3. Before the pre-test starts, we will complete the information requested at the top of the answer sheet as follows (*Please do not fill out the items until asked to do so*): Notice that your student number has already been placed to the right of the word "Name" by your teacher. We *do not* want your name on this answer sheet, only your student number. Move over to the blank called "Sex." If you are a boy, mark "M" for "male;" and if you are a girl, mark "F" for "female." Now go to the second line and print the name of your school on the blank beside the word "School." Now skip over to "Grade or Class" and place the number of your grade or class on the blank provided. Where it says "Instructor" you are to place your teacher's number in the blank provided.

4. All answers should be marked with a *soft lead* pencil. (This is the type of pencil you usually use. Please *do not* use a pen of any kind for marking on the special answer sheet.) This answer sheet will be machine scored. Therefore it is important that you make dark lines that fill the area between the pairs of lines. *Completely erase any marks you wish to change*. Do not make any extra marks on the answer sheet for they could count against you. All figuring should be done on the back side of the answer sheet.

   Notice the SAMPLE question on the answer sheet. The correct answer is #4 and is indicated on the answer sheet by darkening the space under 4.

   1   2   3   4   5

   When you want to answer a question, find the number of the question on the answer sheet. Then look to the right of this number until you find the smaller number that represents the correct response. Darken the space under this small number. (Note: The items go from LEFT to RIGHT on the answer sheet.)

5. Please follow while your teacher reads each item and then carefully complete each item.

6. There is only one correct response to each question. DO NOT LEAVE ANY ITEMS BLANK.

Test Booklet Number: ☐

Laboratory Section

SECTION #1

One student should go to each work station. Take your test and answer sheet with you.

Linear

Remove the white ribbon and the meter/decimeter stick from the kit and place them at your work station. These items will be used for questions 1 and 2. (Note: These items may have been left out at the work station by another student.)

1. Measure the distance between the points labeled "A" and "C" on the white ribbon. The two points are ________ ___________ apart.
   (number) (SI symbol)

   1. 2 m
   2. 3 m
   3. 19 dm
   4. 2 dm
   5. 2 cm

   Please mark your answer beside the corresponding item number on the special answer sheet.

2. Measure the distance between the points labeled "B" and "E" on the white ribbon. The two points are ________ ___________ apart.
   (number) (SI symbol)

   1. 35 dm
   2. 25 dm
   3. 4 m
   4. 3 m
   5. 2 m

   Please mark your answer beside the corresponding item number on the special answer sheet.

Leave the meter/decimeter stick and the white ribbon at the work station for use by another student.

3. Measure the length of this paper to the nearest decimeter. It is approximately ________ (number) ________ (SI symbol) long.

1. 4 m
2. 3 m
3. 4 dm
4. 3 dm
5. 1 dm

Please mark your answer beside the corresponding item number on the special answer sheet.

4. Remove the round wooden dowel rod from the kit. (Note: This item may have already been placed at the work station by another student.) Measure the length of the dowel rod in decimeters. It is exactly ________ (number) ________ (SI symbol) long.

1. 8 dm
2. 7 dm
3. 6 m
4. 7 m
5. 8 m

Please mark your answer beside the corresponding item number on the special answer sheet.

Leave the dowel rod at the work station for use by another student.

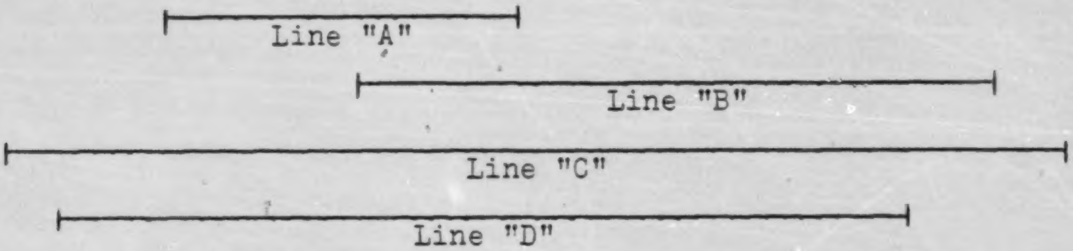
5. Remove the gold ribbon from the kit. (Note: This item may have already been placed at the work station by another student.) Measure the length of the ribbon in decimeters. It is exactly ________ (number) ________ (SI symbol) long.

1. 4 dm
2. 5 dm
3. 6 dm
4. 5 m
5. 4 m

Please mark your answer beside the corresponding item number on the special answer sheet.

Leave the gold ribbon at the work station for use by another student.

Remove the orange centimeter stick from the kit. (Note: This item may have already been placed at the work station by another student.) You will need to measure the lines below when answering questions 6 through 9.



6. Use the centimeter stick to determine the length of line "A". Line "A" is ________ ____________ long.
(number) (SI symbol)

1. 5 cm
2. 7 cm
3. 9 cm
4. 6 dm
5. 5 dm

Please mark your answer beside the corresponding item number on the special answer sheet.

7. Use the centimeter stick to determine the length of line "B". Line "B" is ________ ____________ long.
(number) (SI symbol)

1. 6 cm
2. 8 cm
3. 9 cm
4. 9 dm
5. 7 dm

Please mark your answer beside the corresponding item number on the special answer sheet.

8. Use the centimeter stick to determine the length of line "C" which is drawn at the top of this page. Line "C" is ________ ____________ long.
(number) (SI symbol)

1. 14 dm
2. 16 dm
3. 12 cm
4. 13 cm
5. 15 cm

Please mark your answer beside the corresponding item number on the special answer sheet.

SECTION #2

One student should go to each work station. Take your test and answer sheet with you.

Volume/Capacity

First place the lid of the kit on the table at your work station so that any sand which is spilled can be saved. Remove the plastic liter measure, the container filled with sand and the plastic funnel from the kit and place them in the lid of the kit at your work station. (Note: These items may have already been placed at the work station by another student.)

10. Remove bottle "C" from the kit and place it at your work station. (Note: This item may have already been placed at the work station by another student.) Measure the liter capacity of bottle "C" by using the material and equipment at the work station. Please use the funnel to aid you in filling bottle "C" to the very top with sand.

    Please do not shake or pack the sand throughout this activity.

    Bottle "C" has a capacity that is closest to:

    1. 1 ℓ
    2. 2 ℓ
    3. 2 mℓ
    4. 2 ℓ
    5. 3 mℓ

    Please mark your answer beside the corresponding item number on the special answer sheet.

Please pour the sand from the liter measure back into the sand container with the aid of the plastic funnel. Leave bottle "C" at the work station for the next person.

11. Remove container "E" from the kit and place it at your work station. (Note: This item may have already been placed at the work station by another student.) Measure the liter capacity of container "E" by using the material and equipment at the work station. Fill container "E" with sand.

    Please do not shake or pack the sand in the container during this activity.

(Problem #11 continued on the next page.)

Container "E" has a capacity that is closest to:

1. 1 ℓ
2. 1 mℓ
3. 2 ℓ
4. 2 mℓ
5. 3 ℓ

Please mark your answer beside the corresponding item number on the special answer sheet.

Please pour the sand from the liter measure back into the sand container with the aid of the plastic funnel. Leave container "E" at the work station for the next person. Do not return the liter measure, the plastic funnel and the sand container to the kit. The student who follows you at the work station will be using them.

Remove the foam rubber block labeled "G" and the wood decimeter stick from the kit and place them at the work station. (Note: These items may have already been placed at the work station by the previous student.)

12. Find the volume, to the nearest cubic decimeter, of the foam rubber block labeled "G" by measuring the block with the wood decimeter stick. Do your figuring on the back side of the answer sheet.

Foam rubber block "G" has a volume or capacity of:

1. 1 cm^3
2. 1 dm^3
3. 3 dm^3
4. 2 cm^3
5. 2 dm^3

Please mark your answer beside the corresponding item number on the special answer sheet.

Please do not return the foam rubber block labeled "G" and the wood decimeter stick to the kit for they will be used by the student who follows you at the work station.

Remove box "I", wood block "M", wood block "K" and the orange centimeter stick from the kit and place them at your work station. (Note: These may have already been placed at the work station by another student.) Do all of your figuring for questions 13 through 15 on the back side of the answer sheet.

13. Find the volume, to the nearest cubic centimeter, of the box labeled "I" by measuring the box with the centimeter stick.

    Box "I" has a volume of:

    1. 7 cm^3
    2. 70 dm^3
    3. 47 cm^3
    4. 70 cm^3
    5. 7 dm^3

    Please mark your answer beside the corresponding item number on the special answer sheet.

Place box "I" to one side as the student who follows you will be using it.

14. Find the volume, to the nearest cubic centimeter, of the wood block labeled "M" by measuring the wood block with the centimeter stick.

    Block "M" has a volume of:

    1. 14 cm^3
    2. 36 cm^3
    3. 144 cm^3
    4. 144 dm^3
    5. 14 dm^3

    Please mark your answer beside the corresponding item number on the special answer sheet.

Place wood block "M" to one side as the student who follows you will be using it.

15. Find the volume, to the nearest cubic centimeter, of the wood block labeled "K" by measuring the wood block with the centimeter stick.

Block "K" has a volume of:

1. 324 cm^3
2. 324 dm^3
3. 32 cm^3
4. 32 dm^3
5. 81 cm^3

Please mark your answer beside the corresponding item number on the special answer sheet.

Please leave wood block "K" and the centimeter stick along with box "I" and wood block "J" at the work station for the next student.

First, place the lid to your kit on the table at your work station so that any sand which is spilled can be saved. Remove the 50 milliliter graduate, the 250 milliliter glass graduate, the container filled with sand, the plastic funnel, bottle "T" and the paper cup labeled "U" from the kit and place them in the lid of the kit at your work station. (Note: These items may have already been placed at the work station by another student.)

16. Measure the milliliter capacity of the bottle labeled "T" by using the material and the equipment at your work station. Fill bottle "T" to the very top with sand. Use the plastic funnel to aid you in pouring from bottle "T" into the 50 milliliter plastic graduate.

The capacity of bottle "T" is closest to:

1. 3 mℓ
2. 8 mℓ
3. 38 mℓ
4. 8 ℓ
5. 38 ℓ

Please mark your answer beside the corresponding item number on the special answer sheet.

Please pour the sand from the plastic graduate back into the sand container with the aid of the plastic funnel. Place bottle "T" to one side as the next student will be using it again.

17. Measure the milliliter capacity of the paper cup labeled "U" by using the material and the equipment at your work station. Fill paper cup "U" to the very top with sand.

    Please do not shake or pack the sand in the container or graduate during this activity.

    Use the plastic funnel to aid you in pouring from paper cup "U" into the 250 mℓ glass graduate.

    The capacity of the paper cup labeled "U" is closest to:

    1. 2 100 mℓ
    2. 1 100 mℓ
    3. 21 ℓ
    4. 110 mℓ
    5. 210 mℓ

    Please mark your answer beside the corresponding item number on the special answer sheet.

Please pour the sand from the glass graduate back into the sand container with the aid of the plastic funnel. Place paper cup "U" to one side as the next student will be using it again. Do not return the materials and equipment to the kit for the student replacing you at the work station will be using them.

Please leave your test booklet at the work station for use by another student.

Place your answer sheet on your teacher's desk as you return to your classroom.

SECTION #3

One student should go to each work station. Take your test and answer sheet with you.

Mass/Weight

Remove the balance scale, the large kilogram mass piece (black) and Object "N" from your kit and place them at the work station. (Note: The objects may have already been left out at the work station by a previous student.)

Check your balance scale and make sure that the pointer is on the long line in the center of the balance when the trays are empty. Call your teacher if the balance scale is not balanced.

18. What is the mass, in kilograms, of Object "N"? Place Object "N" on the left pan of the balance and the kilogram mass piece on the right pan. Look at the pointer. The mass of Object "N" is closest to:

    1. 1 kg
    2. 2 kg
    3. 3 kg
    4. 1 g
    5. 2 g

    Please mark your answer on the special answer sheet.

Remove the kilogram mass piece and Object "N" from the pans of the balance and leave them at your work station for use by another student.

Remove the balance scale, mass set and the plastic amber-colored cylinders labeled "O" and "R" from the kit and place them at the work station. (Note: They may have already been placed at the work station by another person.)

Problem Set A:

What is the mass, in grams, of Object "O"? Place Object "O" on the left pan of the balance and answer the following questions:

19. Place the 20 gram mass piece on the right pan. The mass of Object "O" is:

    1. less than 20 g
    2. 20 g
    3. more than 20 g
    4. 20 kg
    5. 10 g

    Please mark your answer beside the corresponding item number on the special answer sheet.

Do not remove the 20 gram mass piece from the right pan as it will be used in the next question.

20. Place the 10 gram mass piece on the right pan along with the 20 gram mass piece. The mass of Object "O" is:

    1. 40 g
    2. more than 30 g
    3. more than 30 kg
    4. 30 g
    5. less than 30 g

    Please mark your answer beside the corresponding item number on the special answer sheet.

Remove only the 10 gram mass piece from the right pan to the mass set. Do not remove the 20 gram mass piece as it will be used in the next question.

21. Place the 5 gram mass piece on the right pan along with the 20 gram mass piece. Object "O" has a mass that is closest to:

    1. 25 kg
    2. 25 g
    3. 20 g
    4. 5 g
    5. 5 kg

    Please mark your answer beside the corresponding item number on the special answer sheet.

Remove the two mass pieces and Object "O" from the pans of the balance. Leave the balance scale and Object "O" at the work station for use by the next student.

Problem Set B:

What is the mass, in grams, of Object "R"? Place Object "R" on the left pan of the balance and answer the following questions:

22. Place the 100 gram mass piece on the right pan. The mass of Object "R" is:

    1. less than 100 g
    2. 100 g
    3. 100 kg
    4. more than 100 g
    5. more than 100 kg

    Please mark your answer beside the corresponding item number on the special answer sheet.

Remove the 100 gram mass piece from the right pan and place it back into the mass set.

23. Place the 50 gram mass piece and the 20 gram mass piece on the right pan. The mass of Object "R" is:

    1. more than 70 kg
    2. more than 70 g
    3. 70 g
    4. 70 kg
    5. less than 70 g

    Please mark your answer beside the corresponding item number on the special answer sheet.

Remove only the 20 gram mass piece from the right pan. Do not remove the 50 gram mass piece as it will be used in the next question.

24. Place the 10 gram mass piece on the right pan along with the 50 gram mass piece. The mass of Object "R" is:

    1. 60 g
    2. 60 kg
    3. more than 60 g
    4. more than 60 kg
    5. 6 kg

    Please mark your answer beside the corresponding item number on the special answer sheet.

Do not remove the 10 gram and 50 gram mass pieces from the right pan as both will be used in the next problem.

25. Place the 5 gram mass piece on the right pan along with the 10 gram and 50 gram mass pieces. Object "R" has a mass that is closest to:

    1. 15 g
    2. 60 g
    3. 60 kg
    4. 65 kg
    5. 65 g

    Please mark your answer beside the corresponding item number on the special answer sheet.

Remove the three mass pieces and Object "R" from the pans of the balance. Place the mass pieces back into the mass set. Leave the objects labeled "N", "O", and "R" at the work station for use by the next student.

Please leave your test booklet at the work station for use by another student.

Place your answer sheet on your teacher's desk as you return to your classroom.

SECTION #4

Temperature

26. Measure, with a Celsius thermometer, the temperature of the ice water provided by your teacher. The ice water is in Container "D", which is located in your classroom. Your teacher will ask that only one student measure the temperature of the ice water at a time. Take your test and answer sheet with you. Place the Celsius thermometer in the container labeled "D" for 60 seconds or for as long as it takes to count (silently) from 1 to 100. Count at a normal pace.

The ice water has a temperature that is closest to:

1. 45 °C
2. 30 °C
3. 16 °C
4. 0 °C
5. -15 °C

Please mark your answer beside the corresponding item number on the special answer sheet.

Place the Celsius thermometer next to container "D" so that the student who will follow you can use it. Return to your seat with test and answer sheet.

27. What is the temperature outside your classroom window? Your teacher has already placed a Celsius thermometer outside of your classroom window. You will be asked to go to the window one at a time and read the thermometer. Take your test and answer sheet with you. The temperature outside is closest to:

1. 45 °C
2. 30 °C
3. 15 °C
4. 0 °C
5. -15 °C

Please mark your answer beside the corresponding item number on the special answer sheet.

Please leave your test booklet at the work station for use by another student.

Place your answer sheet on your teacher's desk as you return to your classroom.

Post-Test--International System of Units (SI)

General Directions

1. This examination consists of 27 multiple choice questions.

2. A special answer sheet accompanies this test booklet.

3. Before the pre-test starts, we will complete the information requested at the top of the answer sheet as follows (Please do not fill out the items until asked to do so): Notice that your student number has already been placed to the right of the word "Name" by your teacher. We do not want your name on this answer sheet, only your student number. Move over to the blank called "Sex." If you are a boy, mark "M" for "male;" and if you are a girl, mark "F" for "female." Now go to the second line and print the name of your school on the blank beside the word "School." Now skip over to "Grade or Class," and place the number of your grade or class on the blank provided. Where it says "Instructor," you are to place your teacher's number in the blank provided.

4. All answers should be marked with a soft lead pencil. (This is the type of pencil you usually use. Please do not use a pen of any kind for marking on the special answer sheet.) This answer sheet will be machine scored. Therefore it is important that you make dark lines that fill the area between the pairs of lines. Completely erase any marks you wish to change. Do not make any extra marks on the answer sheet for they could count against you. All figuring should be done on the back side of the answer sheet.

   Notice the SAMPLE question on the answer sheet. The correct answer is #4 and is indicated on the answer sheet by darkening the space under 4.

   1 2 3 4 5

   When you want to answer a question, find the number of the question on the answer sheet. Then look to the right of this number until you find the smaller number that represents the correct response. Darken the space under this small number. (Note: The items go from LEFT to RIGHT on the answer sheet.)

5. Please follow while your teacher reads each item and then carefully complete each item.

6. There is only one correct response to each question. DO NOT LEAVE ANY ITEMS BLANK.

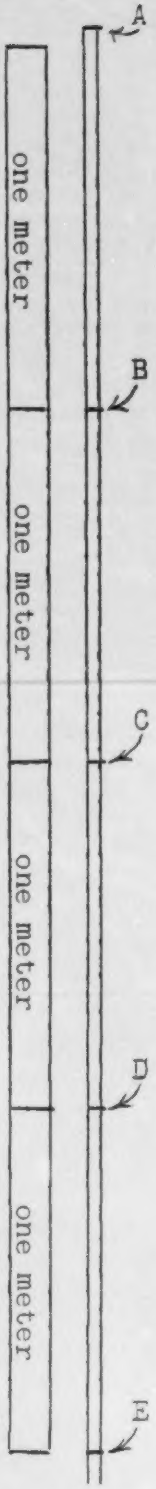
Test Booklet Number: ☐

Simulated Section

SECTION #1

Linear

Look to the front of the classroom. Your teacher will display for you the white ribbon and the meter stick which are drawn to scale on the right.



1. Determine the distance between the points labeled "A" and "B" on the white ribbon which is pictured on the right. The two points are ________ __________ apart.
(number) (SI symbol)

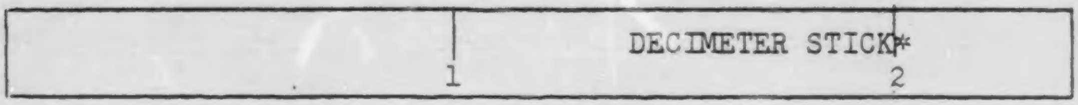
1. 3 m
2. 2 m
3. 1 m
4. 9 dm
5. 11 dm

Please mark your answer beside the corresponding item number on the special answer sheet.

2. Determine the distance between the points labeled "A" and "E" on the white ribbon which is pictured on the right. The two points are ________ __________ apart.
(number) (SI symbol)

1. 31 dm
2. 39 dm
3. 2 m
4. 3 m
5. 4 m

Please mark your answer beside the corresponding item number on the special answer sheet.

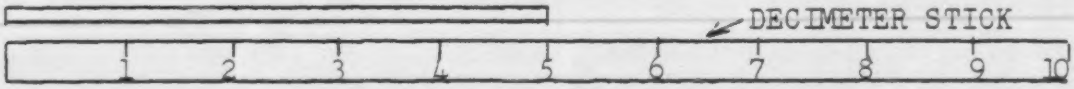


3. Determine the width of this page to the nearest decimeter by reading the scale pictured at the top of this page.* It is approximately ______ ________ wide.
(number) (SI symbol)

1. 3 m
2. 2 m
3. 3 dm
4. 2 dm
5. 1 dm

Please mark your answer beside the corresponding item number on the special answer sheet.

4. Look again to the front of the classroom. Your teacher will display for you a wooden dowel rod and decimeter stick which are drawn to scale below.



Determine the length of the dowel rod by reading the scale above. The dowel rod is ______ (number) ________ (SI symbol) long.

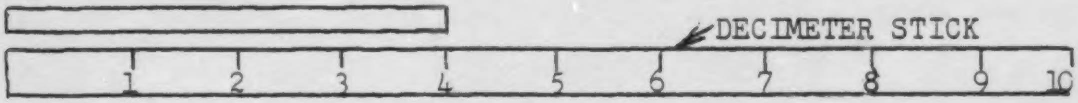
1. 3 dm
2. 4 dm
3. 5 dm
4. 4 m
5. 5 m

Please mark your answer beside the corresponding item number on the special answer sheet.

---

* This drawing is reduced 30% from the original.

5. Look once again to the front of the classroom. Your teacher will display for you a green ribbon and the decimeter stick which are drawn to scale below.

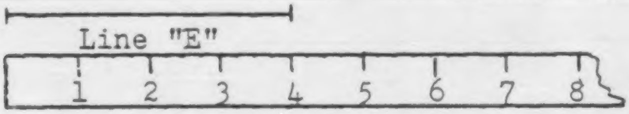


Determine the length of the green ribbon by reading the scale above. The ribbon was found to be ________ __________ long.
(number) (SI symbol)

1. 3 dm
2. 4 dm
3. 5 dm
4. 4 m
5. 3 m

Please mark your answer beside the corresponding item number on the special answer sheet.

6. Determine the length of line "E" by reading the full size centimeter stick pictured just below:

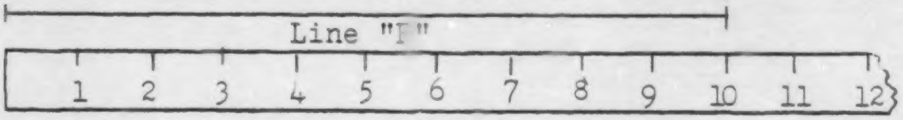


Line "E" is ________ __________ long.
(number) (SI symbol)

1. 3 cm
2. 4 cm
3. 5 cm
4. 4 dm
5. 3 dm

Please mark your answer beside the corresponding item number on the special answer sheet.

7. Determine the length of line "F" by reading the full size centimeter stick pictured just below.

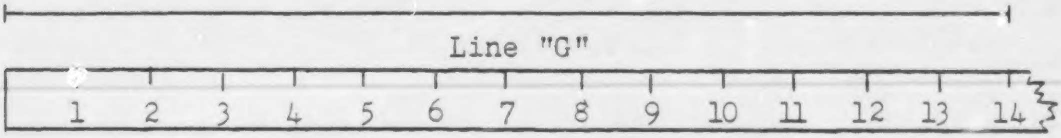


Line "F" is ________ ____________ long.
(number) (SI symbol)

1. 10 cm
2. 9 cm
3. 7 cm
4. 8 dm
5. 10 dm

Please mark your answer beside the corresponding item number on the special answer sheet.

8. Determine the length of line "G" by reading the full size centimeter stick pictured just below.

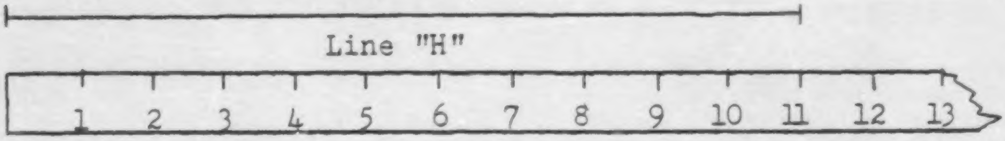


Line "G" is ________ ____________ long.
(number) (SI symbol)

1. 11 cm
2. 12 cm
3. 13 dm
4. 14 cm
5. 15 dm

Please mark your answer beside the corresponding item number on the special answer sheet.

9. Determine the length of line "H" by reading the full size centimeter stick pictured just below.



Line "H" is ________ ___________ long.
(number) (SI symbol)

1. 1 dm
2. 10 dm
3. 14 cm
4. 12 cm
5. 11 cm

Please mark your answer beside the corresponding item number on the special answer sheet.

SECTION #2

Volume/Capacity

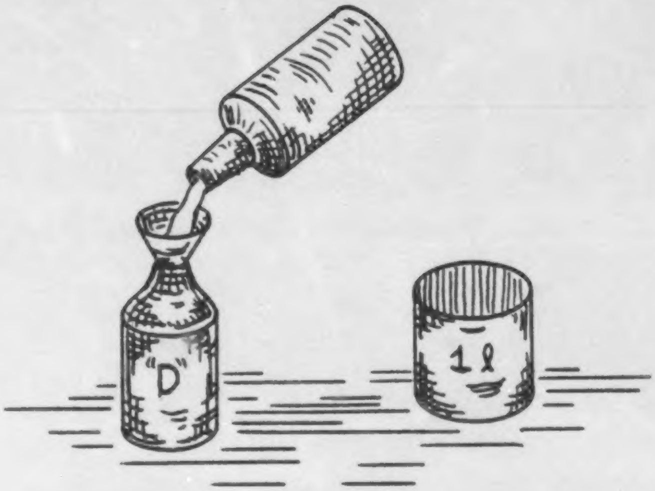
10. Look to the front of the classroom. Your teacher will be holding bottle "D" and a 1-liter measure that are drawn to scale on the following page. The drawings on the following page show bottle "D" being filled to the black mark with sand and then being emptied into the liter measure. Determine the liter capacity of bottle "D" by reading the scale of the liter measure shown in Step #3. The shaded portion of the liter measure drawn in the two views located in Step #3 represents the sand on the inside.

Bottle "D" has a capacity that is closest to:

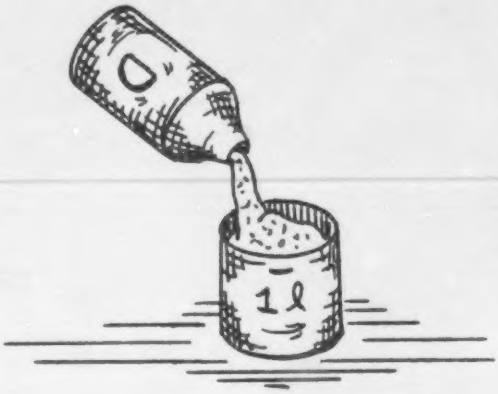
1. 3 ℓ
2. 3 mℓ
3. 2 ℓ
4. 2 mℓ
5. 1 ℓ

Please mark your answer beside the corresponding item number on the special answer sheet.

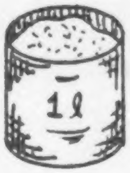
STEP 1*



STEP 2*



STEP 3*



OR

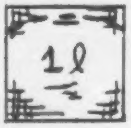


FIGURE #1

Figure #1 shows the liter measure when it is level.

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* This page is reduced 15% from the original

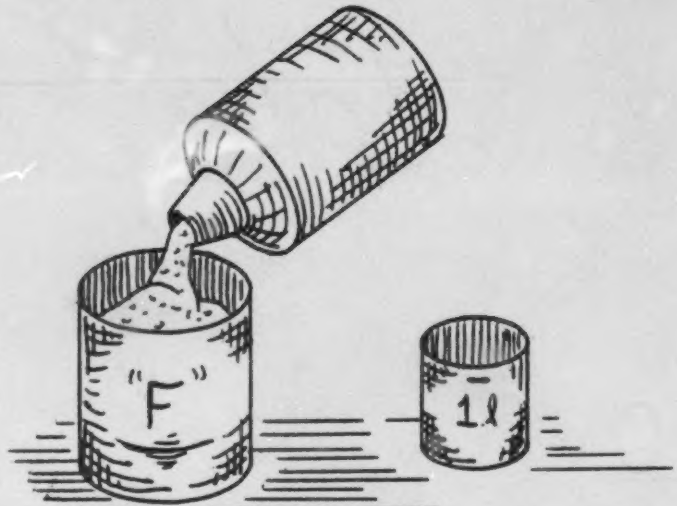
11. Look to the front of the classroom. Your teacher will be holding container "F" and a 1-liter measure that are drawn to scale on the next page. The drawings on the next page show container "F" being filled with sand and then being emptied into the liter measures. Determine the liter capacity of container "F" by reading the scale of the liter measures shown in Step #3. The shaded portion of the liter measure drawn in the two views located in Step #3 represents the sand on the inside.

Container "F" has a capacity of:

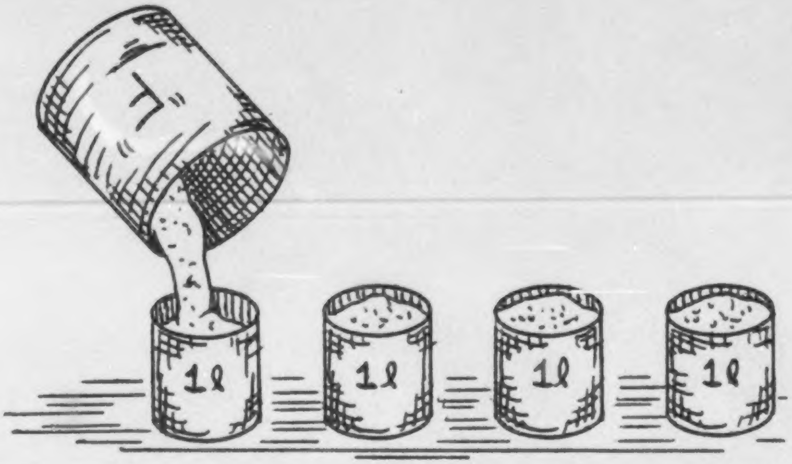
1. 2 mℓ
2. 3 ℓ
3. 3 mℓ
4. 4 ℓ
5. 4 mℓ

Please mark your answer beside the corresponding item number on the special answer sheet.

STEP 1*



STEP 2*



STEP 3 *

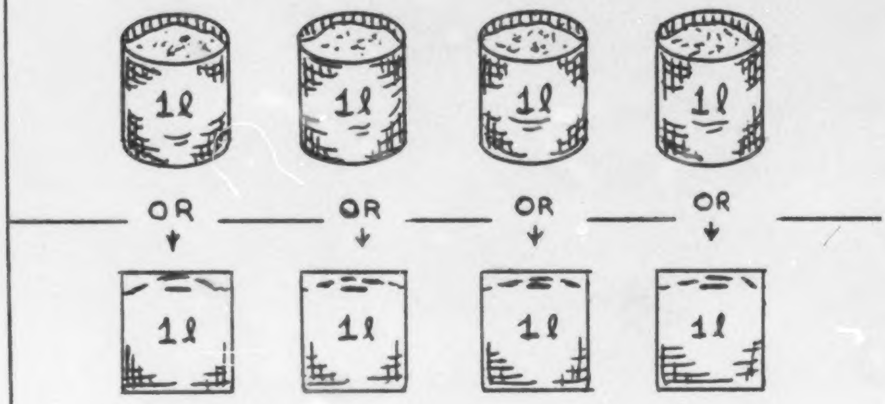

1l
1l
1l
1l
OR
OR
OR
OR
1l
1l
1l
1l

FIG. 1 FIG. 1 FIG. 1 FIG. 1

Figures #1 show the liter measures when they are level.

---

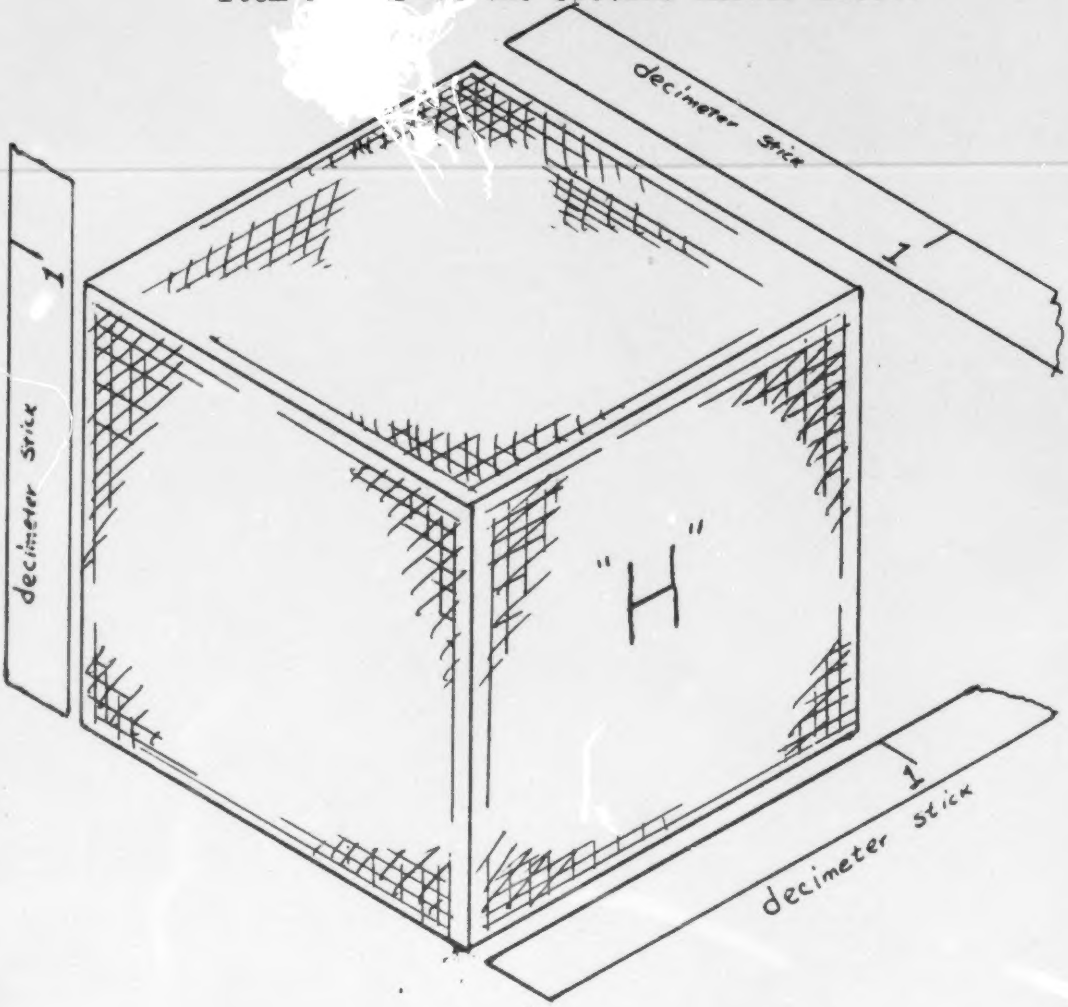
*This page is reduced 15% from the original

12. Look to the front of the classroom. Your teacher will be holding the foam rubber block labeled "H" and the wood decimeter stick that are drawn to scale below. Find the volume, to the nearest cubic decimeter, of the foam rubber block labeled "H" by using the decimeter sticks pictured next to the sides of the block.

Foam rubber block "H" has a volume of:

1. 1 cm^3
2. 1 dm^3
3. 2 cm^3
4. 2 dm^3
5. 3 dm^3

Please mark your answer beside the corresponding item n[illegible]er on the special answer sheet.


decimeter stick
1
decimeter stick
1
"H"
1
decimeter stick

SECTION #3

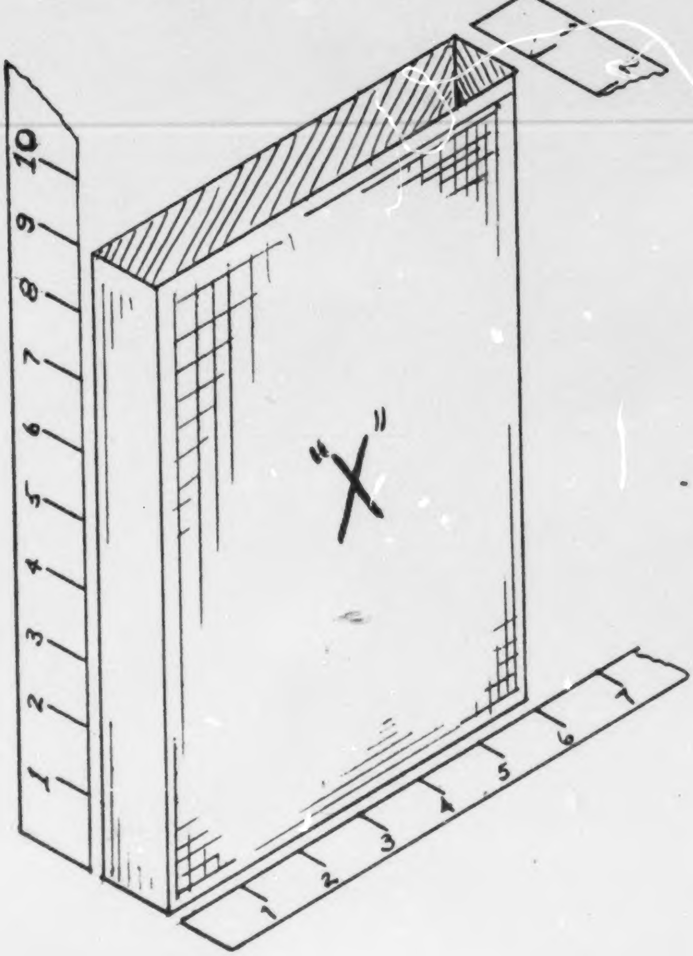
Volume/Capacity Con't.

13. Find the volume, in cubic centimeters, of box "X" which is drawn full size below. Use the centimeter sticks pictured next to the box to arrive at your answer.

Box "X" has a volume of:

1. 6 cm^3
2. 9 cm^3
3. 54 cm^3
4. 54 dm^3
5. 9 dm^3

Please mark your answer beside the corresponding item number on the special answer sheet.

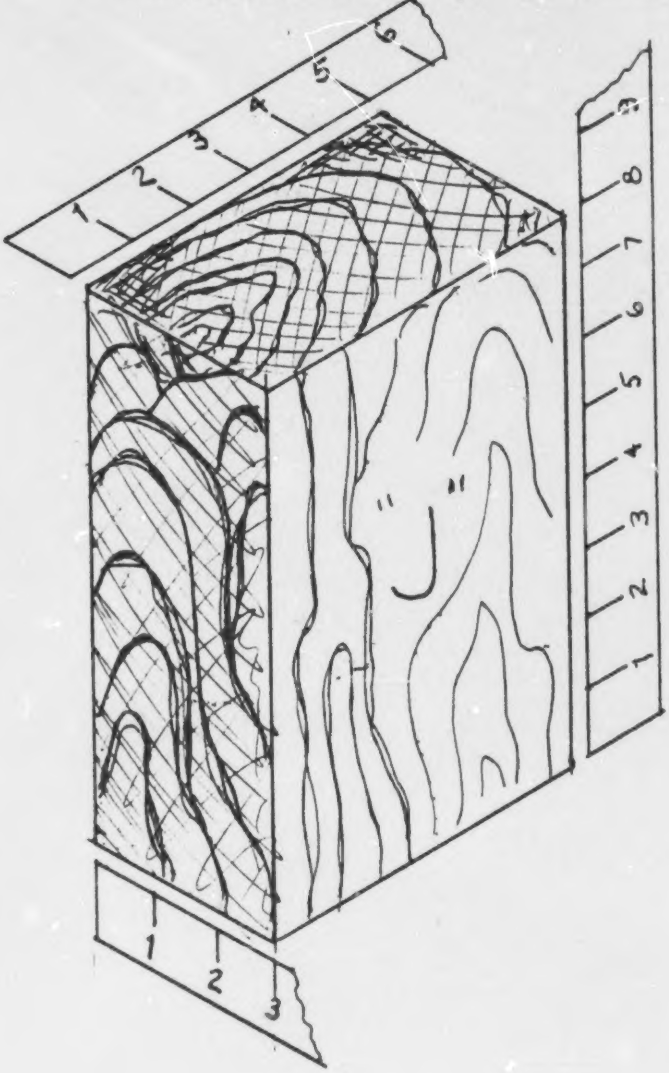


14. Find the volume, in cubic centimeters, of the wood block labeled "J" which is drawn full size below. Use the centimeter sticks positioned next to the wood block to arrive at your answer.

Block "J" has a volume of:

1. 15 cm^3
2. 40 cm^3
3. 24 cm^3
4. 120 cm^3
5. 120 dm^3

Please mark your answer beside the corresponding item number on the special answer sheet.

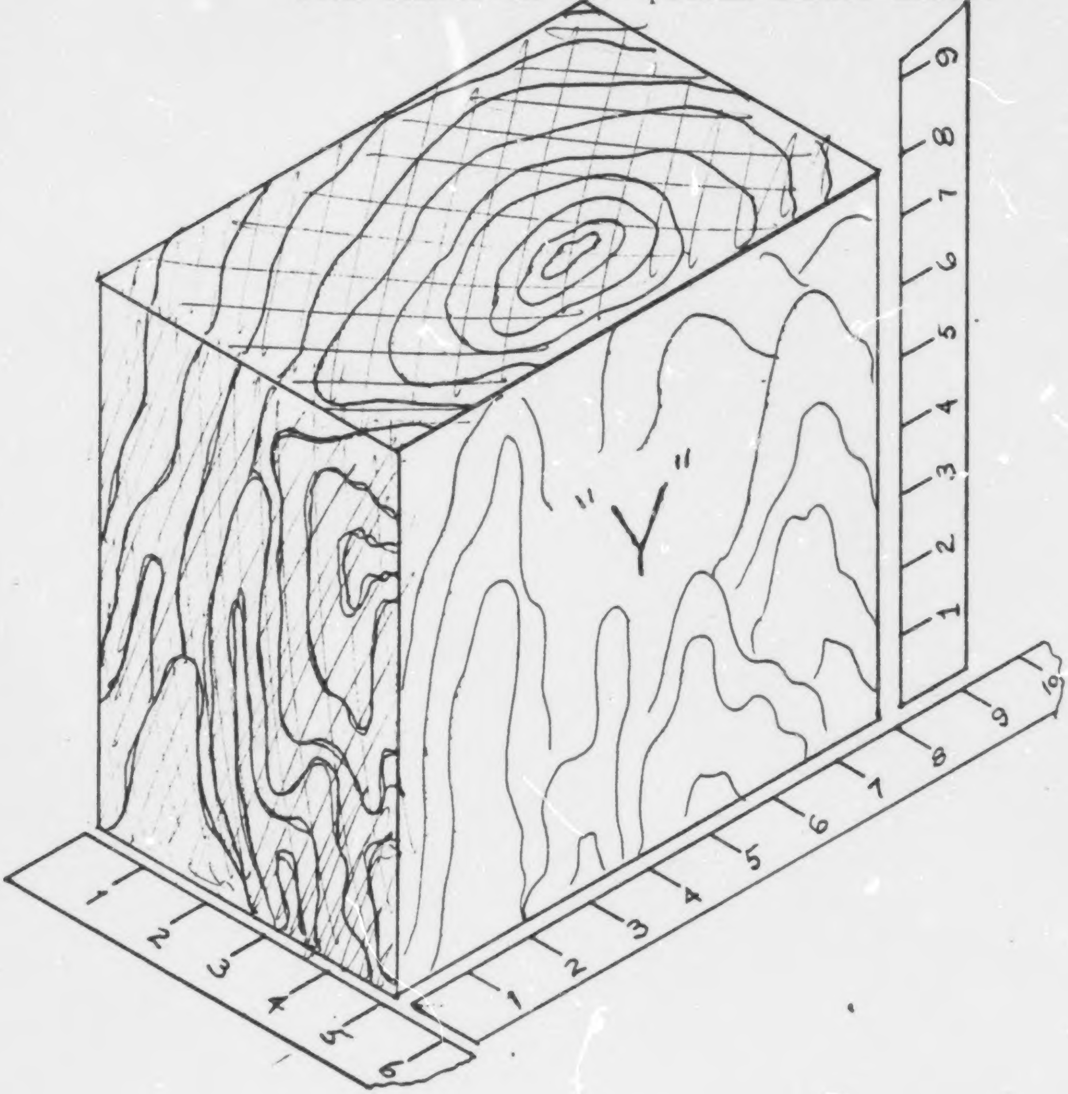


15. Find the volume, in cubic centimeters, of the wood block labeled "Y" which is drawn full size below. Use the centimeter sticks positioned next to the wood block to arrive at your answer.

Block "Y" has a volume of:

1. 40 cm^3
2. 64 cm^3
3. 320 cm^3
4. 320 dm^3
5. 32 dm^3

Please mark your answer beside the corresponding item number on the special answer sheet.



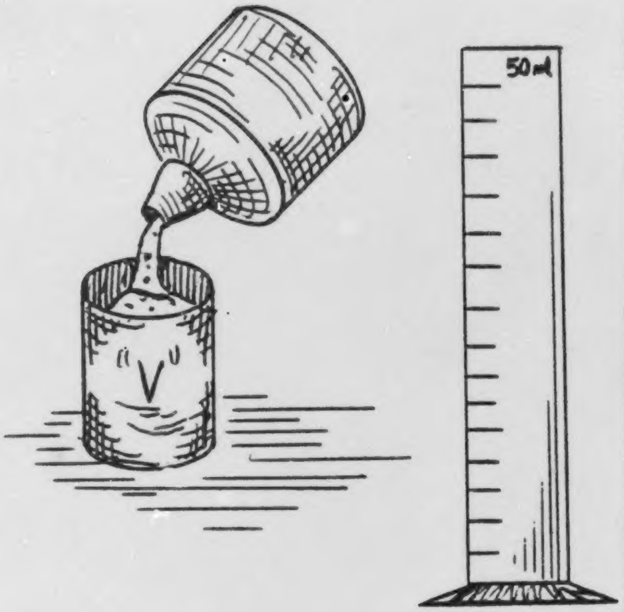
16. Look to the front of the classroom. Your teacher will be holding bottle "V" and a 50 milliliter plastic graduate that are drawn on the next page. The drawings on the left side of the next page show bottle "V" drawn to scale as well as being filled with sand and then being emptied into the 50 milliliter graduate. Determine the milliliter capacity of bottle "V" by reading the scale of the full size graduate shown on the following page in Step #3. The shaded portion of the graduate drawn in Step #3 represents the sand on the inside.

Bottle "V" has a capacity that is closest to:

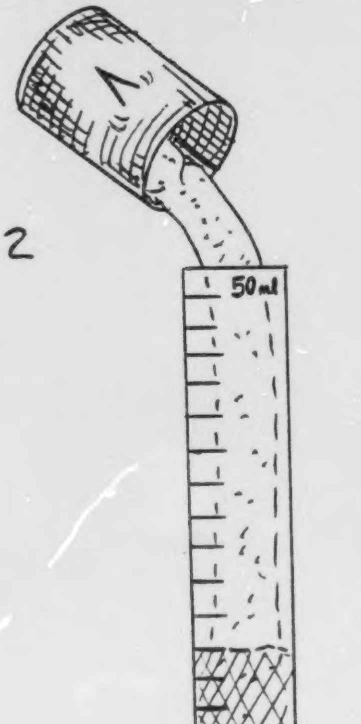
1. 7 ℓ
2. 17 ℓ
3. 7 mℓ
4. 10 mℓ
5. 17 mℓ

Please mark your answer beside the corresponding item number on the special answer sheet.

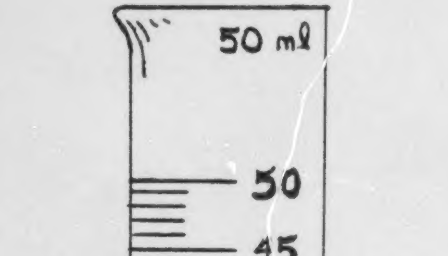
STEP 1



STEP 2



STEP 3


50 ml
50
45
40
35
30
25
20
15
10
5

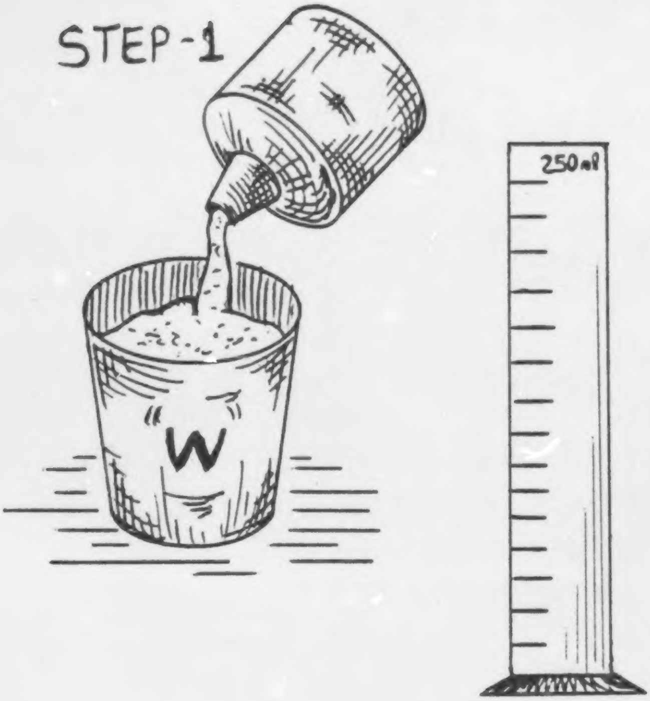
17. Look to the front of the classroom. Your teacher will be holding paper cup "W" and a 250 milliliter glass graduate that are drawn on the next page. The drawings on the left side of the next page show paper cup "W" drawn to scale as well as being filled with sand and then being emptied into the 250 milliliter glass graduate. Determine the milliliter capacity of paper cup "W" by reading the scale of the graduate shown in Step #3. The shaded portion of the graduate drawn in Step #3 represents the sand on the inside.

Paper cup "W" has a capacity that is closest to:

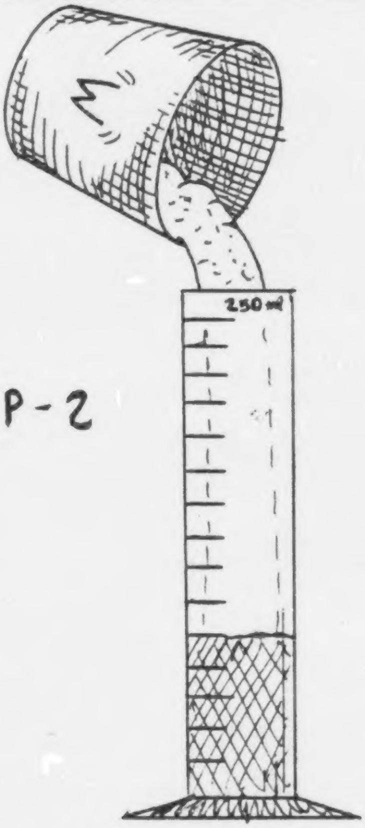
1. 3 ℓ
2. 13 mℓ
3. 130 mℓ
4. 1 300 mℓ
5. 130 ℓ

Please mark your answer beside the corresponding item number on the special answer sheet.

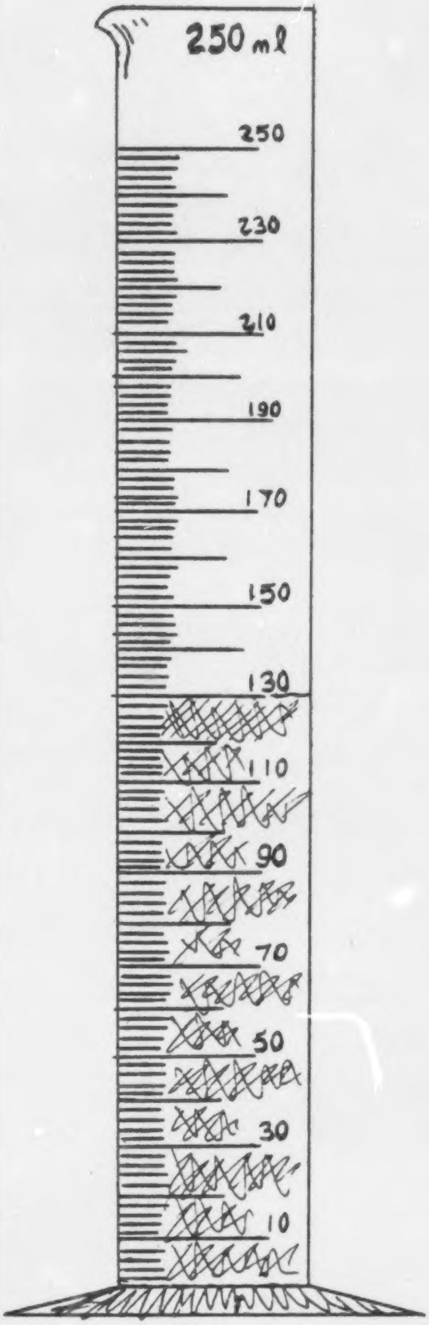
STEP-1



STEP-2



STEP - 3


250 ml
250
230
210
190
170
150
130
110
90
70
50
30
10

SECTION #4

Mass/Weight

18. What is the mass, in kilograms, of Object "Y" which is shown in Figure #1?

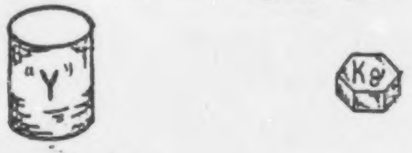
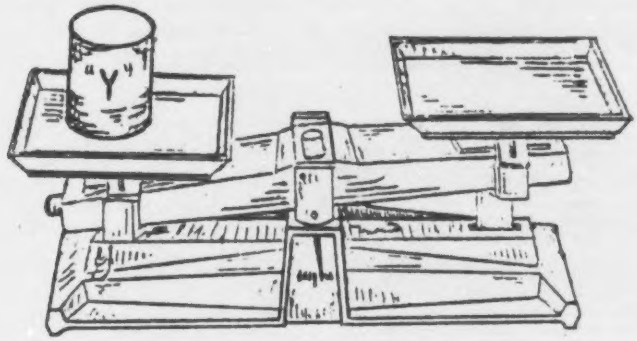
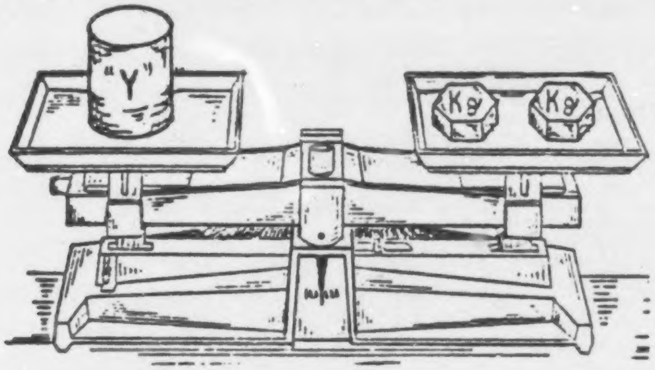


Figure #1

Object "Y" is shown below on the left pan of the balance.



Two kilogram mass pieces have been placed on the right pan in the picture below.



The mass of Object "Y" is:

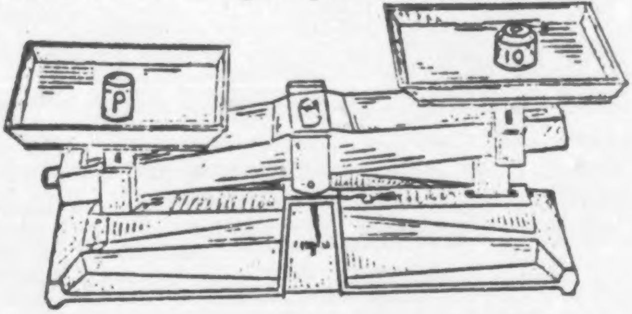
1. 1 kg
2. 2 kg
3. 3 kg
4. 2 g
5. 1 g

Place the answer beside the corresponding item number on the special answer sheet.

Problem Set A:

What is the mass, in grams, of Object "P"? Object "P" is shown below on the left pan of the balances.

19. A 10 gram mass piece from the mass set has been placed on the right pan in the picture below.

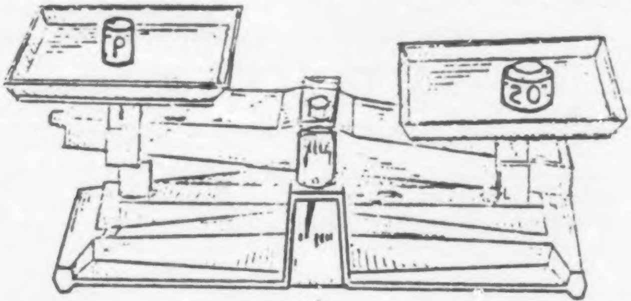


The mass of Object "P" is:

1. 10 g
2. less than 10 g
3. more than 10 g
4. 9 g
5. 10 kg

Please mark your answer beside the corresponding item number on the special answer sheet.

20. Below you see that the 10 gram mass piece has been replaced with a 20 gram mass piece.

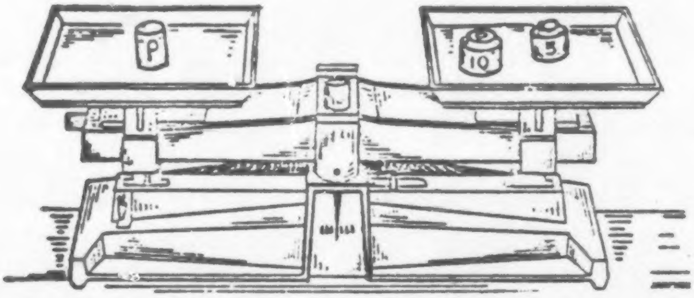


The mass of Object "P" is:

1. 20 g
2. less than 20 g
3. more than 20 g
4. more than 20 kg
5. 21 g

Please mark your answer beside the corresponding item number on the special answer sheet.

21. Below you see that the 20 gram mass piece has been replaced with a 10 gram mass piece and a 5 gram mass piece.



The mass of Object "P" is:

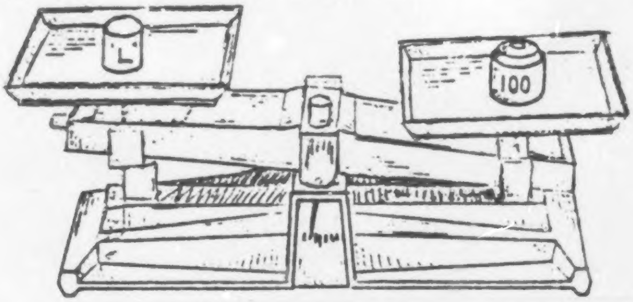
1. 10 kg
2. 5 kg
3. 10 g
4. 15 g
5. 15 kg

Please mark your answer beside the corresponding item number on the special answer sheet.

Problem Set B:

What is the mass, in grams, of Object "L"? Object "L" is shown below on the left pan of the balances.

22. A 100 gram mass piece from the mass set has been placed on the right pan in the picture below.

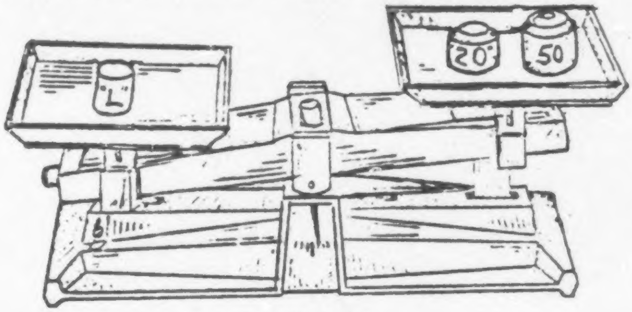


The mass of Object "L" is:

1. less than 100 g
2. 100 g
3. 100 kg
4. more than 100 g
5. more than 100 kg

Please mark your answer beside the corresponding item number on the special answer sheet.

23. Below you see that the 100 gram mass piece on the right pan has been replaced with a 50 gram mass piece and a 20 gram mass piece.

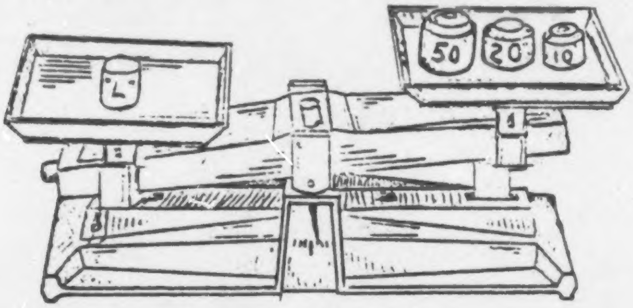


The mass of Object "L" is:

1. less than 70 g
2. more than 70 g
3. 70 g
4. 70 kg
5. less than 50 g

Please mark your answer beside the corresponding item number on the special answer sheet.

24. Below you see that an additional 10 gram mass piece was added to the 50 gram and the 20 gram mass pieces on the right pan.

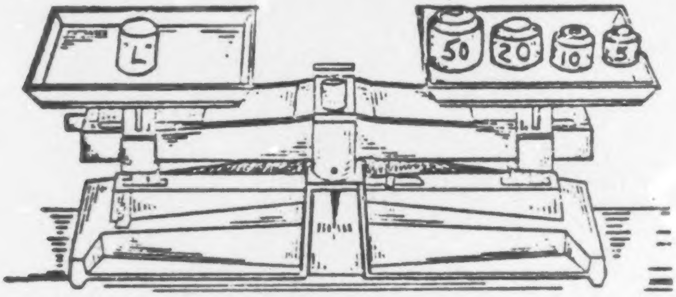


The mass of Object "L" is:

1. 80 g
2. 70 g
3. more than 80 g
4. less than 80 g
5. less than 70 g

Please mark your answer beside the corresponding item number on the special answer sheet.

25. Below you see that an additional 5 gram mass piece was added to the 50 gram, 20 gram and 10 gram mass pieces on the right pan.



The mass of Object "L" is:

1. 75 g
2. 75 kg
3. 85 g
4. 85 kg
5. 70 g

Please mark your answer beside the corresponding item number on the special answer sheet.

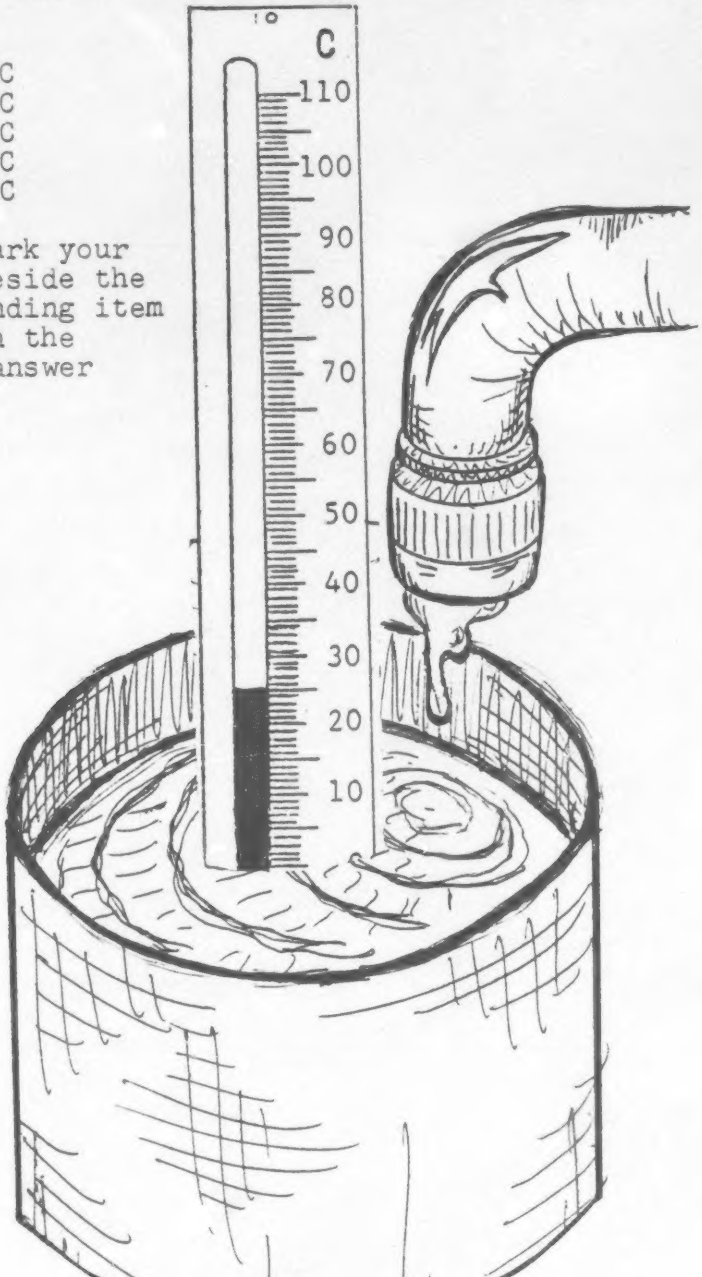
SECTION #5

Temperature

26. Below is pictured a Celsius thermometer that has been placed for 60 seconds in a container filled with tap water (cold). The cold tap water pictured below has a temperature that is closest to:

1. 45 °C
2. 30 °C
3. 15 °C
4. 0 °C
5. -15 °C

Please mark your answer beside the corresponding item number on the special answer sheet.



27. On the next page you see a Celsius thermometer that has been placed outside of a classroom window during a mild spring day.* The temperature outside, as pictured on the next page, is closest to:

1. 45 °C
2. 30 °C
3. 15 °C
4. 0 °C
5. -15 °C

Please mark your answer beside the corresponding item number on the special answer sheet.

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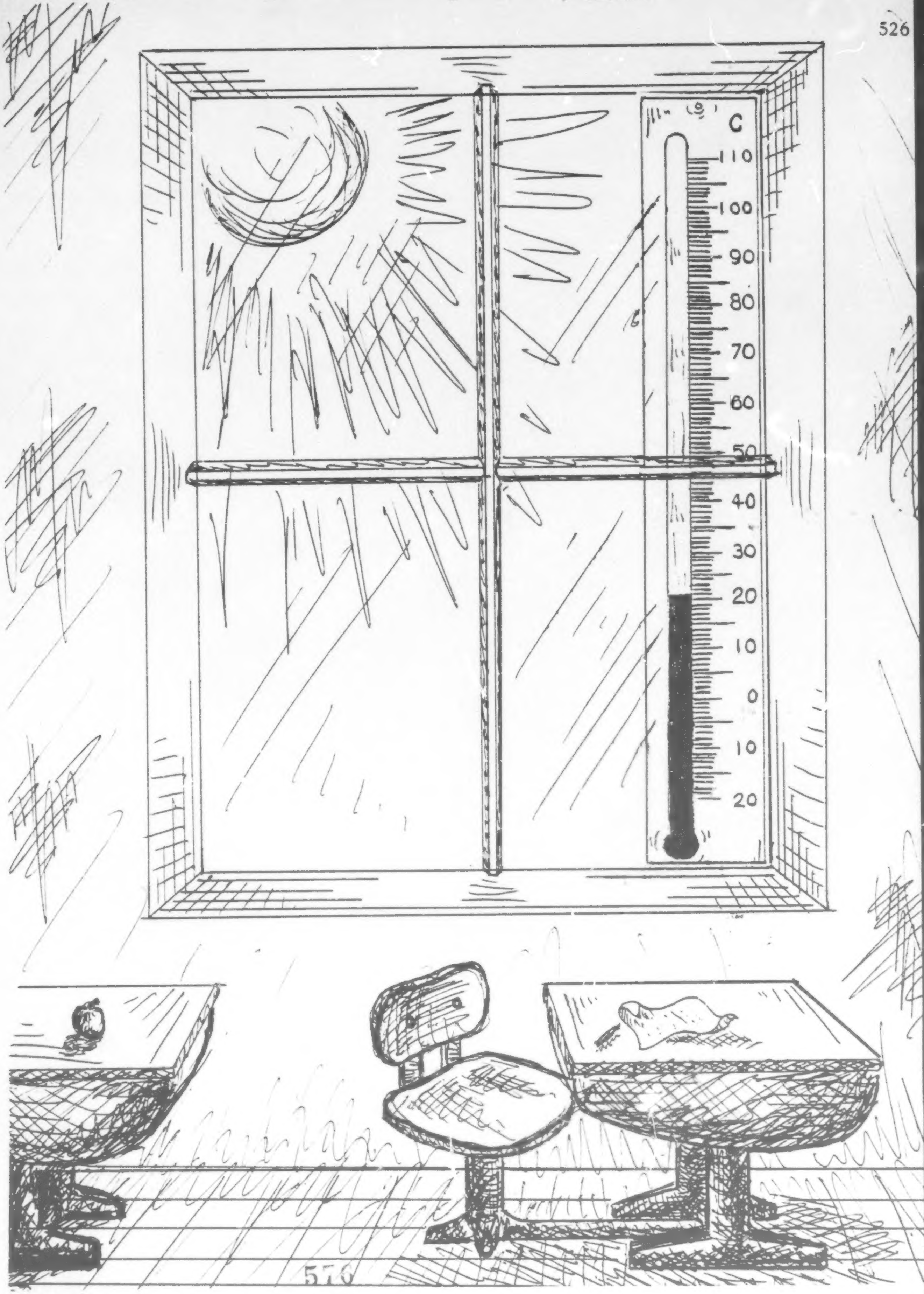
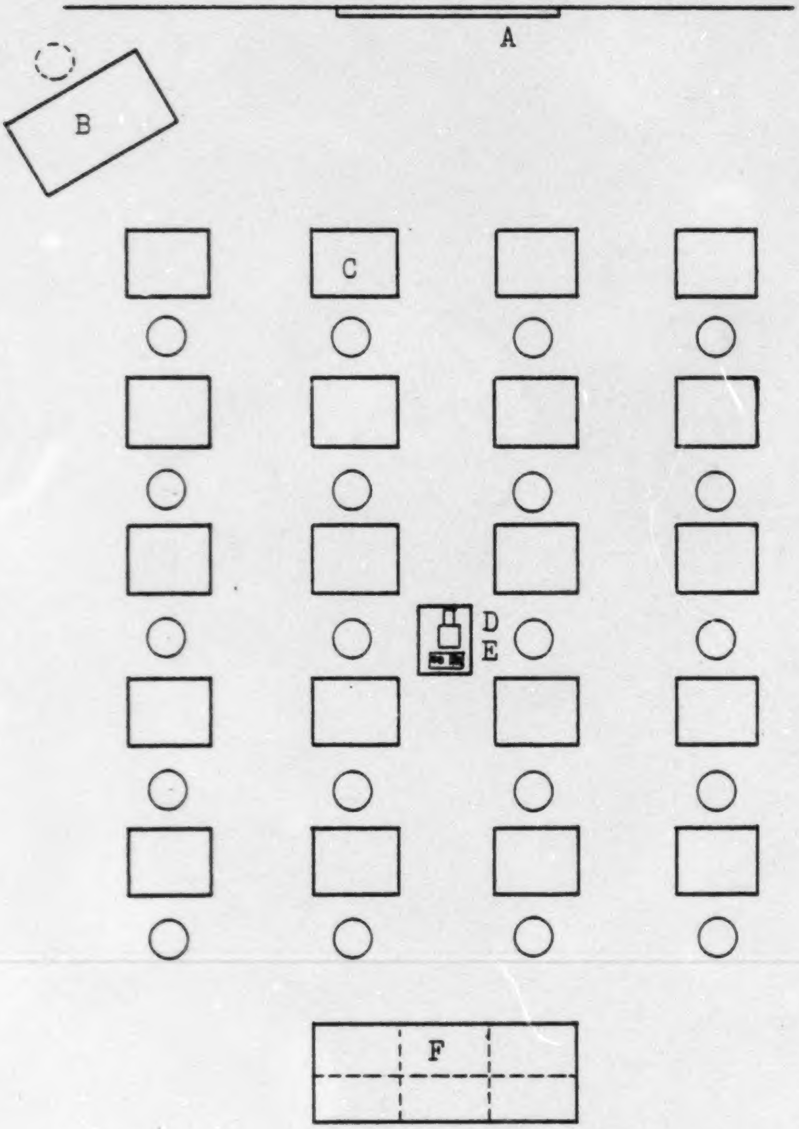
*The drawing on the next page is reduced 23% from the original.


C
110
100
90
80
70
60
50
40
30
20
10
0
10
20

APPENDIX G

Equipment Setup for Conducting the Experiment

Equipment Setup for Conducting the Experiment

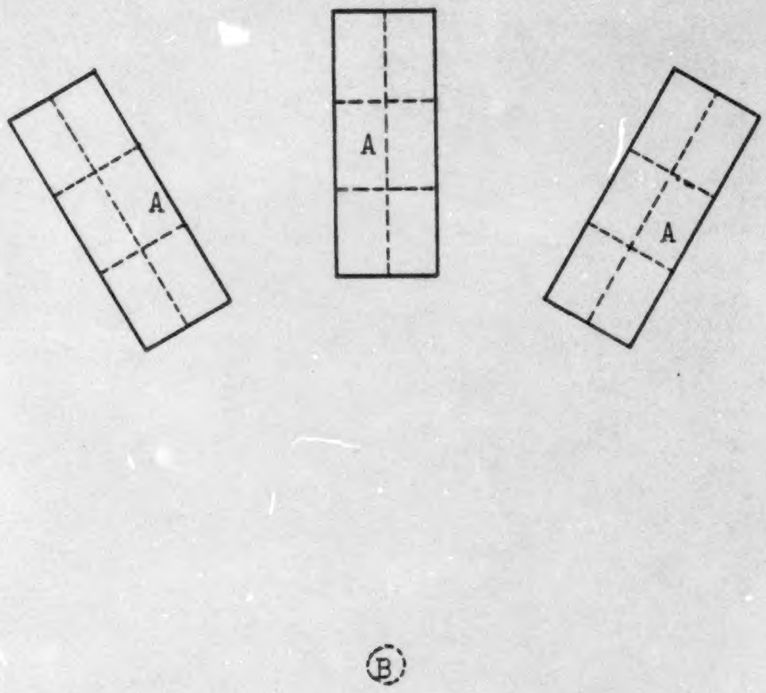


A. Projection screen
B. Teacher's desk
C. Student's desk
D. Slide projector
E. Cassette tape player
F. Work table

APPENDIX H

Equipment Setup for Administering the Final Instrument

Equipment Setup for Administering the Final Instrument



A. Work table
B. Teacher

APPENDIX I

Attitude Inventory

METRIC ATTITUDE INVENTORY

Directions

This inventory contains a number of questions about how you think and feel about metric measurement. The metric system of measurement has been used by many countries of the world for a number of years. It is based on a pattern of 10's and uses a series of prefixes such as deci, milli, centi and kilo along with such suffixes as meter, liter and gram.

The customary or English system of measurement is the type of measuring system which has been used for a number of years in the United States. It uses a number of measuring units such as inches, feet, pounds, ounces, bushels and quarts to mention but a few.

There are a number of people who are suggesting that the United States change from the customary or English system of measurement to the metric system. We are interested in your ideas about the following statements which are related to measurement.

If you AGREE with the statement, blacken the space between the dashed lines under the small number 1. If you DISAGREE with the statement, you are to blacken the space between the dashed lines under the small number 3. and if you are NOT SURE whether you agree or disagree with the statement, you are to darken the space between the dashed lines under the small number 5.

Turn the page and read each statement silently as your teacher reads then aloud. Your teacher will read each statement twice and will then allow you a few seconds to blacken your response.

Turn the page and begin.

ATTITUDE INVENTORY

1. I dread the thought of learning how to measure things by using the metric system of measurement.

2. I feel that learning to measure in the metric system can become an enjoyable experience.

3. The metric system will benefit more people in the United States than will our present day customary or English system of measurement.

4. The rest of the world should change to our customary or English system of measurement.

5. I feel that one big disadvantage of the metric system is that it is more complicated to use than our present day customary or English system of measurement.

6. It will be more fun to measure things in metrics than it is to measure them by our customary or English system of measurement.

7. If the customary or English system was better understood, then we would not need to change to the metric system of measurement.

8. The thought of learning the metric system of measurement frightens me a little.

9. It will make life more complicated in the United States if we change from the customary or English system of measurement.

10. The United States should make the change to the metric system of measurement because nearly uses it as their system of measurement.

11. The customary or English system of measurement has several undesirable features.

12. Changing to the metric system of measurement would accomplish nothing worthwhile either for the individual or for our society.

13. The metric system of measurement should be practiced by all Americans.

14. The metric system of measurement would be easier for children to learn than our present day customary or English system.

15. I feel that changing to the metric system of measurement would be a waste of time and money.

16. I like the customary or English system of measurement too well to give it up.

17. The prefixes and suffixes which are used in the metric system make that system more difficult to learn.

18. The metric system of measurement has more disadvantages than advantages.

19. The metric system of measurement has several undesirable features.

20. It would be easier to buy and sell materials by the metric system than by our present day customary or English system since things in the metric system can be divided or multiplied by 10.

21. Although our customary or English system has several undesirable features, I would rather continue to use it than to learn to use the metric system of measurement.

22. I feel that it would be too costly to change over our household measuring devices to the metric system of measurement.

23. The customary or English system of measurement has more disadvantages than advantages.

24. Since the metric system uses decimals, it should be easier to learn than our present day customary or English system of measurement which uses fractions.

25. A big advantage of the metric system is that it will allow us to measure things faster than we could by our present day customary or English system of measurement.

26. I think that the American people would adjust fairly easily to the metric system of measurement if we do change to that system.

27. If changing to the metric system will allow the nations of the world to conserve natural resources, then the United States should switch to the metric system of measurement.

28. The relative ease with which one unit in the metric system can be compared with another unit makes it a very desirable system of measurement.

29. Since it would not be practical to change everything over to the metric system of measurement, then we should stay with our present day customary or English system.

30. The metric system of measurement promises to solve some of our greatest measurement problems.

APPENDIX J

Pretest--International System of Units

Pre-Test--International System of Units (SI)

General Directions

1. The purpose of this pre-test is to determine how much you know about SI Measurement.

2. A special answer sheet accompanies this test booklet.

3. Before the pre-test starts, we will complete the information requested at the top of the answer sheet as follows (Please do not fill out the items until asked to do so): Notice that your student number has already been placed to the right of the word "Name" by your teacher. We do not want your name on this answer sheet, only your student number. Move over to the blank called "Sex." If you are a boy, mark "M" for "male;" and if you are a girl, mark "F" for "female." Now go to the second line and print the name of your school on the blank beside the word "School." Now skip over to "Grade or Class," and place the number of your grade or class on the blank provided. Where it says "Instructor," you are to place your teacher's number in the blank provided.

4. All answers should be marked with a soft lead pencil. (This is the type of pencil you usually use. Please do not use a pen of any kind for marking on the special answer sheet.) This answer sheet will be machine scored. Therefore it is important that you make dark lines that fill the area between the pairs of lines. Completely erase any marks you wish to change. Do not make any extra marks on the answer sheet for they could count against you.

   Notice the SAMPLE question on the answer sheet. The correct answer is #4 and is indicated on the answer sheet by darkening the space under 4.

1	2	3	4	5
===	===	===	▬	===

   When you want to answer a question, find the number of the question on the answer sheet. Then look to the right of this number until you find the smaller number that represents the correct response. Darken the space under this small number. (Note: The items go from LEFT to RIGHT on the answer sheet.)

5. Please follow while your teacher reads each item and then carefully complete each item.

6. There is only one correct response to each question. DO NOT LEAVE ANY ITEMS BLANK.

Test Booklet Number: ☐

1. The basic unit of length in the International System of Units is the

    1. degree Celsius
    2. kilogram
    3. liter
    4. meter
    5. yard

2. The basic unit of mass/weight in the International System of Units is the

    1. degree Celsius
    2. kilogram
    3. liter
    4. meter
    5. pound

3. The scale most commonly used for temperature in the International System of Units is

    1. Celsius
    2. Centigrade
    3. Fahrenheit
    4. Kelvin
    5. none of the above

4. When we think of International System of Units we usually think of it as a system of

    1. arithmetic
    2. materials
    3. measurement
    4. money
    5. tools

5. The prefix deci is used to represent

    1. 1 000
    2. 100
    3. 10
    4. .1
    5. .01

6. A recipe reads, "Heat the water to its boiling point, then add the soup mixture." The temperature of the boiling water will be

    1. 37 °C
    2. 60 °C
    3. 100 °C
    4. 140 °C
    5. 180 °C

7. The liter has approximately the same volume as a

   1. gallon jug
   2. pint bottle
   3. quart jar
   4. drinking glass
   5. space inside a small thimble

8. The mass or weight of one kilogram of steel is

   1. the same as one pound
   2. the same as two pounds
   3. a little less than two pounds
   4. a little more than two pounds
   5. approximately ten pounds

9. The centigrade thermometer, when used in the International System of Units, is given the name of

   1. Celsius thermometer
   2. Fahrenheit thermometer
   3. Kelvin thermometer
   4. International System of Units thermometer
   5. none of the above

10. The prefix used to represent .001 is

    1. centi
    2. deka
    3. hecto
    4. kilo
    5. milli

11. Which of the following is not used to make a measurement greater than a meter?

    1. kilometer
    2. millimeter
    3. hectometer
    4. dekameter
    5. all are measures which are greater than a meter

12. The cubic centimeter has the same volume as

    1. one cubic decimeter
    2. one dekaliter
    3. one liter
    4. one microliter
    5. one milliliter

13. One cubic centimeter of distilled water has a mass/weight of

    1. one gram
    2. one milligram
    3. one kilogram
    4. two dekagrams
    5. two grams

14. The Celsius thermometer has __?__ units between the boiling point of water and the freezing point of water.

    1. 37
    2. 68
    3. 100
    4. 180
    5. 212

15. The prefix used to represent 100 is

    1. centi
    2. deka
    3. hecto
    4. kilo
    5. milli

16. One (1) kilometer equals

    1. 1 000 meters
    2. 100 meters
    3. .1 meter
    4. .01 meter
    5. .001 meter

17. Which of the following cubic measurements has the same volume as does the liter?

    1. one cubic centimeter
    2. one cubic decimeter
    3. one cubic dekameter
    4. one cubic kilometer
    5. one cubic millimeter

18. Of the following units, which is best to use when measuring the contents of a box of cereal?

    1. gram
    2. hectogram
    3. kilogram
    4. metric ton
    5. milligram

19. Which of the following body temperatures is considered to be normal?

    1. 40 °C
    2. 39 °C
    3. 38 °C
    4. 37 °C
    5. 36 °C

20. Which of the following prefixes is misplaced if they are arranged from the smallest to the largest?

    1. centi
    2. milli
    3. deci
    4. deka
    5. kilo

21. If you were to divide a meter into 100 equal parts, each part would be called a

    1. millimeter
    2. hectometer
    3. dekameter
    4. decimeter
    5. centimeter

22. The basic unit of volume in the International System of Units is the
    1. degree Celsius
    2. kilogram
    3. gallon
    4. liter
    5. meter

23. If a container filled with distilled water has a mass/weight of one kilogram, it has a volume of

    1. one hectoliter
    2. one liter
    3. one milliliter
    4. two dekaliters
    5. two liters

24. If you wanted to go ice skating on a lake, the temperature of the ice should be

    1. 0 °C
    2. 25 °C
    3. 50 °C
    4. 75 °C
    5. 100 °C

25. The prefix kilo is used to represent

    1. .01
    2. .1
    3. 10
    4. 100
    5. 1 000

26. Ten centimeters are the same as

    1. one decimeter
    2. one dekameter
    3. one hectometer
    4. one millimeter
    5. one meter

27. The unit which is used to measure the volume of medicine given to a patient is the

    1. centiliter
    2. deciliter
    3. hectoliter
    4. liter
    5. milliliter

28. The unit that is used to measure the mass/weight of one brick is the

    1. centigram
    2. gram
    3. kilogram
    4. milligram
    5. metric ton

29. Which of the following is not used to make a measurement less than a meter?

    1. millimeter
    2. centimeter
    3. decimeter
    4. dekameter
    5. all are measures of less than a meter

30. Which of the following statements is true?

    1. one meter equals one yard
    2. one meter is less than one yard
    3. one yard is just a little less than one meter
    4. one yard is just a little larger than one meter
    5. none of the statements are true

A COMPARISON OF INSTRUCTIONAL APPROACHES TO TEACHING THE INTERNATIONAL SYSTEM OF WEIGHTS AND MEASURES TO ELEMENTARY SCHOOL CHILDREN WITH VARYING MENTAL ABILITY

ABSTRACT

Purpose. The purpose of this study was to ascertain the relative effect of two instructional approaches upon the attitude, knowledge, laboratory achievement and simulated achievement and retention of fourth, fifth and sixth grade students who studied the International System of Units (SI). The two instructional approaches were: Approach A, the laboratory activity approach required students to physically measure three-dimensional objects with metric scales, and Approach B, the simulated approach in which students identified measurements from pictures of two-dimensional objects along side of which metric scales are printed. The study was also designed to investigate the effect that laboratory and simulated test types might have upon the achievement and retention of fourth, fifth and sixth grade students. The attitude of the teachers toward the International System of Units was also assessed.

Method of research. The instructional materials and instruments utilized in the study were designed around the lesson objectives. Three educators validated the

instructional materials and instruments, while a pilot test established the instruments' reliability. The study was conducted during the spring of 1974-75 school year in Warrensburg, Missouri. The fourth, fifth and sixth grade students who participated in the study were from three elementary schools. Since students had already been assigned to classes in advance, the researcher accepted the classes as they were and randomly assigned the instructional approaches to the intact classes. The experimental factor which was varied for each of the two instructional groups was the student activity whereby the students experienced selected content in SI measurement. The procedure required the control or equalization of factors affecting the student learning of SI measurement, except the experimental factor which was the instructional approach. This experimental factor was varied for each of two groups in the experiment. Measures of the dependent variable were secured immediately after the treatments to ascertain the relative effect of each approach upon the variables. Three weeks after the posttest, a test of retention was administered. All data were analyzed statistically by the analysis of covariance through multiple regression technique with attitude and cognitive pretest scores along with mental ability scores serving as covariates. The level of significance was chosen as 0.05.

Findings and conclusions. The findings of this investigation revealed that a significant difference did exist among group mean attitude posttest scores of sixth grade students, regardless of their prior attitude toward and prior knowledge of SI measurement as well as their mental ability level. Therefore, it may be concluded that under the conditions of this investigation, sixth grade students who experience either the laboratory approach or the simulated approach will exhibit a greater differential effect in their attitude toward SI measurement favoring the laboratory approach (Approach A).

The data obtained from this investigation failed to reveal a significant difference in the effect of Approach A (laboratory activities) and Approach B (simulated activities) on group mean cognitive scores of SI measurement for fourth, fifth and sixth grade students. It was also ascertained that the effects of Approach A to Approach B upon informational retention were not significantly different. Therefore it may be concluded that, under the conditions of this investigation, there will not be a differential effect upon cognitive knowledge and retention of fourth, fifth and sixth grade students as a result of exposure to the laboratory approach (Approach A) or the simulated approach (Approach B) to studying SI measurement.

The findings of this investigation also failed to reveal a significant difference in the effect of Approach A (laboratory activities) and Approach B (simulated activities) on group mean informational achievement and retention scores of SI measurement for fourth, fifth and sixth grade students. Therefore it may be concluded that, under the conditions of this investigation, there will not be a differential effect in initial achievement retention by students as a result of exposure to the laboratory approach (Approach A) or the simulated approach (Approach B) to studying SI measurement.

When comparisons were made between the laboratory and simulated sections of the achievement and retention tests, the findings revealed that a significant difference did exist among group mean scores of fourth, fifth and sixth grade students, regardless of their prior knowledge of SI measurement and mental ability level. Therefore it may be concluded, that under the conditions of this investigation, fourth, fifth and sixth grade students who experience both the simulated and laboratory sections of the achievement and retention test, will exhibit a greater differential effect favoring the simulated section of the test.

The findings of this investigation also failed to reveal a significant interaction between instructional approaches and test types, regardless of prior knowledge of SI measurement and levels of mental ability for fourth, fifth and sixth grade students. Therefore it may be concluded that, under the conditions of this investigation, there is no significant interaction between instructional approaches and laboratory and simulated test types that affect the ability of fourth, fifth and sixth grade students to make SI measurements.

When comparisons were made between pre attitude and post attitude measures of the twelve teachers involved in the study, a significant difference was found for both approaches. Therefore it may be concluded that teachers will show a greater differential effect favoring SI measurement, regardless of the instructional approach utilized although group mean scores favor the laboratory approach (Approach A).